# DATA PROCESSING

## IN BUSINESS AND INDUSTRY

January-March 1959 Number 1 Volume 1

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# Data Processing

IF data processing can be described in a single sentence, it is the technique whereby information is acquired, transmitted, stored, retrieved and operated upon for effective industrial and commercial use. There is nothing new in the fact of data being processed, but, understandably, the advent of electronic computers has placed fresh, ever-increasing emphasis on the development of truly efficient administration. With the allied equipment there are new and potentially immensely valuable aids to this end.

This journal, *Data Processing*, is designed to keep top management and chief executives abreast of the new methods: to reveal where and in what way they can be applied to businesses, large and small. Consequently, commercial and industrial rather than scientific applications will be described and discussed. These can have a greater immediate effect on productivity and, in the main, the problems involved are common to all types of business.

### Industrial unbalance

Few need reminding, for example, that the two aspects of industry—administration and manufacture—have become unbalanced. A transfer-line can produce hundreds, maybe many thousands, of parts in a day under the control of three or four operatives; in other sections of the same factory there will be a far larger labour force employed in ordering material for these parts, progressing that material, dealing with orders, scheduling, despatching, invoicing and so on. Data processing can help to reverse this ever-increasing trend towards unbalance. Indeed, a stage will be reached when the present separate industrial entities, office and works, are integrated into a common unit. Similarly, in purely commercial firms the various departmental offices will become more nearly integrated and a more efficient, more cohesive organization will result.

A fresh era is being ushered in. Many clerical jobs that can be defined in detail can be performed by a machine. If the conditions governing a particular task remain the same for a considerable time and the volume of work is large, it is reasonably certain that a machine can perform the operation more quickly, more accurately and at lower cost. Among the tasks now performed by machine are the preparation of warehouse loading orders, pay rolls, stock control, machine-tool loading, the selection of specific items of information from a file, spare-part ordering, preparing invoices and, not least, budgetary control. This last leads to what can be the most important matter of all: the problem which can bedevil management, namely, that close financial control is impossible because the exact operational state of the organization is never known. The stocks of raw material may be out of balance—some items over-ordered, others in short supply. Stock requirements may not be adjusted quickly enough in response to variations in the sales pattern. Tempo of production cannot be changed sufficiently rapidly to accommodate changes in demand. Or perhaps, slow ossification of the system has set in because the internal volume of paper circulated is sapping energies

## FRESH AIDS TO GREATER EFFICIENCY

—usurping time that could be employed more, much more, remuneratively.

Data processing does not, inevitably, imply access to a computer. Although the computer is the most powerful of the data processing tools, steam hammers are not required to crack nuts. Many industrial problems can be solved by the use of simpler, cheaper equipment. It is a common experience for computer manufacturers, when asked to advise on a particular application, to have to tell a would-be customer that for his problem he does not require a computer.

### Punched card applications

In many such cases the answer lies in punched card machinery. Originally conceived for statistical work, this machinery soon came to be adopted by accountants, but curiously the industrial world as a whole was—and, in the main, still is—oblivious to the full potentialities of this type of equipment. The engineering industries, in particular, have many problems that can be solved by these means, as an increasing number of companies is realizing. Hence this journal will discuss not only electronic computers, their applications and their limitations, but also punched card machinery—and, in fact, data processing in all those forms which are calculated to make a positive contribution to greater efficiency and, therefore, lower cost.

Data processing also tends to reduce the amount of drudgery. For instance, instead of the manual recording of results from visual scrutiny, with its limitations and liability to error, there is now data logging and, allied with it, data reduction. The information on the workings of a process or the results of a test are automatically recorded, transmitted, selected and interpreted, and presented in an immediately intelligible form at preselected intervals of time. Linked with the instrumentation there can be controls which take corrective action should the process or test go beyond prescribed limits.

Quite simple forms of computing equipment can be used for this purpose, plus, of course, the data logging units. In general, however, computers at the moment are large, costly and have far greater capacities than a small firm can usefully employ. These facts have been realized and equipment is being developed that will be more appropriate to the needs of the smaller concerns. Even some very small firms already have extensive punched card installations, and it is only a matter of time before many such firms buy and operate their own small computers.

Descriptions of the best of the latest operational practices, the use of the equipment—punched card machinery, computers, and what is termed "peripheral equipment"—this is the subject matter of *Data Processing*. And the aims and objects of new designs will be revealed and—most important—interpreted. There will also be information on the characteristics and uses to which more specialized machines, such as *x-y* plotters and other data reduction and logging equipment, are being put.

New techniques, fresh tools, are available now; there are many developments on the way. Our purpose and our mission is to provide the essential information on these techniques and equipment that management to-day must have.

# The computing service

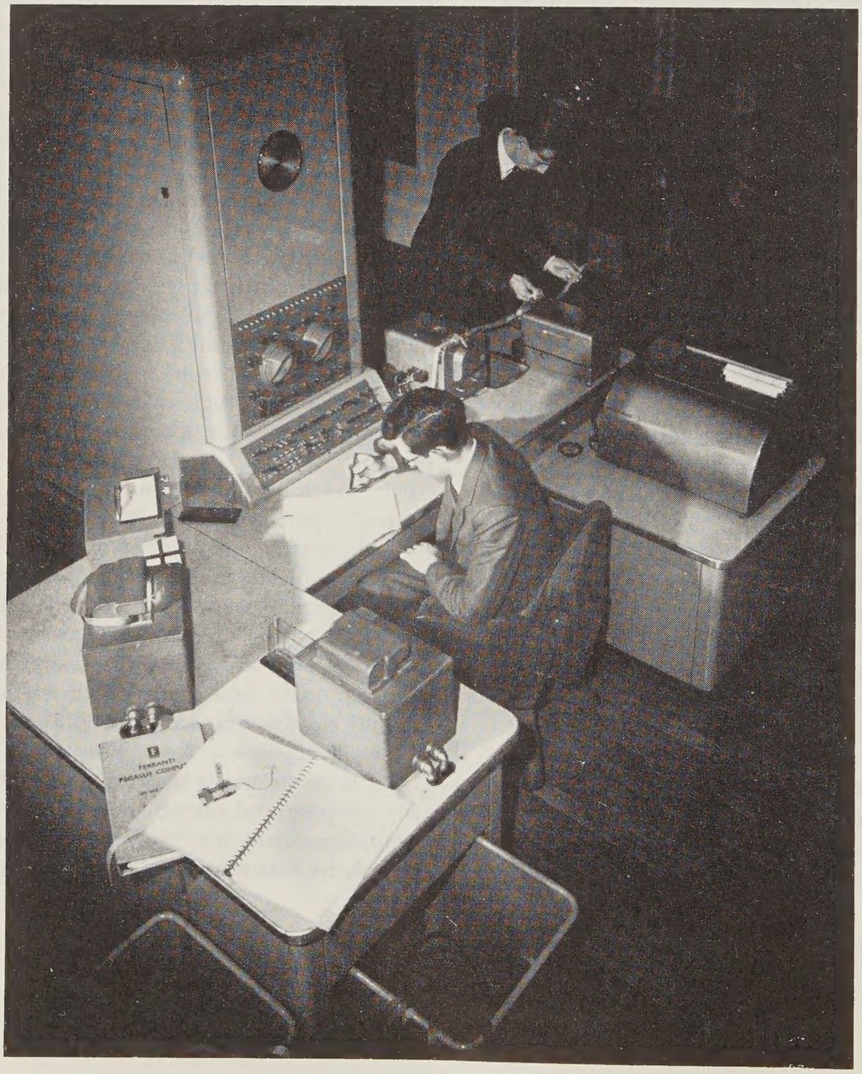
By P. L. Young*

There is nothing new in the idea of using a computing service instead of owning a computer but, with the increased demand for computation, the character and structure of the computing service has changed. Less than 10 years ago it was thought that the demand would not be great and that a few computing centres would be established to deal with the work of single countries, or groups of small countries. In fact, the demand for computation was greatly underestimated.

In the early days of computing it was also thought that a small body of specialists at each installation would undertake the solution of all the problems. Now the idea is that the man with the problem should learn to use the computer and tackle the work himself. The difference is that between a laundry and a launderette.

The main argument in favour of this latter approach is that the man with the problem knows the intricacies of his work, can formulate the problem precisely and can learn quickly how to write the instructions for the computer—in other words, the programme. Often, it takes less time to learn how to use a computer than to explain the problem, without risk of misunderstanding, to a specialist programmer.

*Fig. 1. Many computing service centres operate on a shift basis and 40 or 50 different jobs may be completed in one day*



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*Mr. P. L. Young is with Ferranti, Ltd.

A story is told of an investigation to find a balanced diet that would give the best nutritional content for the smallest cost. The first result of this imperfectly formulated problem prescribed an exclusive diet of cheese. An error might not always be so obvious.

Most organizations begin to use a computer through a computing service. The process is gradual; it begins in a small way, with, perhaps, one calculation to be done as an experiment by the design office. This is followed by others until a range of problems is being tackled. Operational experience is gained by hiring time on various machines. In this way, computer operations and their economics can be assessed in relation to the needs of the organization before the final commitment of buying a computer is undertaken.

Gradually, the use made of the service increases. More and more problems are put on to the computer, as it is realized that problems previously thought unsuitable for the machine can, in fact, be tackled. The computer itself creates enthusiasm as people become familiar with its capabilities. Individuals become keen to use the machine to solve their problems. By using a computer, for example, an experienced designer can rid himself of much of the drudgery of detailed calculation and spend more time at his fundamental job of designing.

Many jobs that are now done on a computer were in the past not attempted or were treated in a simplified and unrealistic manner because they were either too big or too tedious with existing procedures. Many new applications have been "discovered" in this way—and some that have proved to be profitable were originally not even foreseen.

Moreover, a man who uses a computer for one job soon sees possible applications to related jobs. Following such a trend, a man accustomed to scientific calculations may well become interested in commercial work. There is an actual instance of one user of a computing service moving from aircraft-design calculations to the calculation of superannuation costs. In this way an organization finds that there is ample scope for an electronic digital computer. In addition to preparing programmes, an organization may consider it worthwhile to possess the transcription equipment needed for preparing the input data in the required form (generally punched cards or punched tape). This has happened with many firms which five years ago saw no possibility of using a computer in their work at all. Electronic computers have, in fact, brought out the latent demand for computation. As the number of jobs done on a computer accumulates, the organization builds up a valuable investment in programmes.

**Training courses**

Because of this new attitude to the use of a computing service, a large number of people want to know how to use these machines. To meet this demand, programming courses are held by manufacturers at their service centres and also by universities, polytechnics and technical colleges. The first correspondence course in programming has just started in this country. Those attending these courses come from many industries—electrical, chemical, aircraft, iron and steel engineering, insurance and banking. There is hardly an industry which is not represented. Generally speaking, the younger the industry the more eager the response to computers. The aircraft and nuclear industries have probably been the largest single users so far.

Most training courses last from a fortnight to a month full time or an equivalent period part-time. In such courses, no previous knowledge of computers is assumed and training consists of lectures, interspersed with practical classes for working through sets of examples. Usually, the lectures cover the technique of programming and a few specific applications for a particular machine. At the end of the course, the student should be able to write complete programmes of his own. Possibly he may even run a simple programme on the computer during his course. An encouraging aspect about these courses is the high attendance, particularly at evening

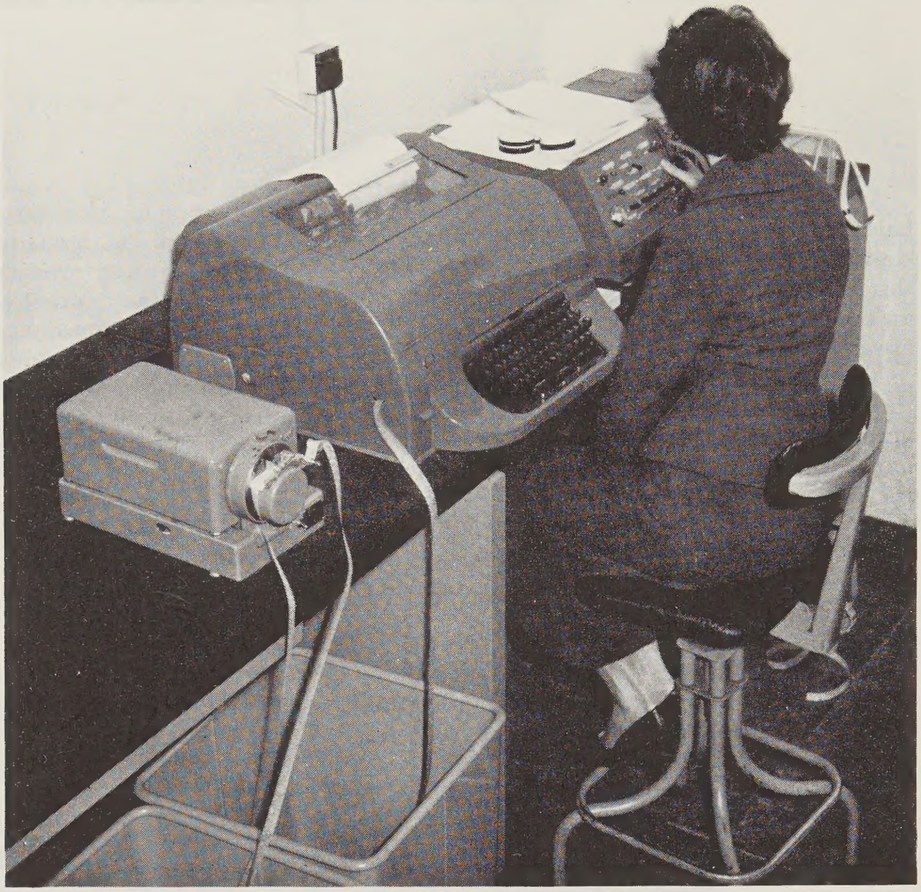


*Fig. 2. Users of a computing service often possess their own transcription equipment and prepare their own punched tapes*

classes, and the readiness of people to study manuals and work through examples in their own time. A recent polytechnic evening course had a following of 200, which speaks highly for the enthusiasm of the individual. One of the interesting results of computer work is the impetus given by the individual to the study and use of computers. This point is illustrated particularly by the rapid growth of the British Computer Society.

For those who do not wish to acquire the complete technique of programming, there are a number of automatic coding schemes which greatly simplify this task. The technique of using automatic programming codes can be acquired in a matter of two or three days. All that is required is for the programme to be written in a more or less natural symbolic notation. This method lengthens the time taken on the computer to obtain the results, but shortens the overall time needed to solve a particular problem. For example, it may take five hours to write a programme which is run on the computer for 10 minutes, but if an automatic programme code is used, the programme may be written, say, in 15 minutes with running time on the computer increased to 30 minutes. Hence, overall time will have been reduced from 5 hours 10 minutes to 45 minutes. Normally the writing and developing of the detailed machine programme occupies most of the time.

For the "one-off" job, or where an answer is required urgently, or the approach to a problem has to be tested, an automatic programming code is the best method. More and more are being devised. The important characteristic of an automatic programming code is that it allows people to tackle their own calculations as part of their normal work. Use of a computer may then become as ordinary and natural as using a conventional desk calculating machine.

## Existing services

Existing services in Great Britain are those run by the computer manufacturers (B.T.M., Elliott Brothers, English Electric, Ferranti, I.B.M., Leo Computers, Powers-Samas and Standard Telephones), by universities (Durham, Glasgow, Leeds, London, Manchester, Oxford, Sheffield and Southampton), by technical colleges (Northampton College of Advanced Technology) and by research associations for member companies (for instance, the British Iron and Steel Research Association). A novel computing service was started a short while ago in Long Island, New York. There, on an industrial estate, a centre was opened to serve the needs of a dozen tenants and other nearby companies. Similar centres are to be opened in Boston and Cincinnati. Such centres could well become a part of the industrial estates in Britain's new towns. It should be added that mobile computers are impracticable owing to technical problems.

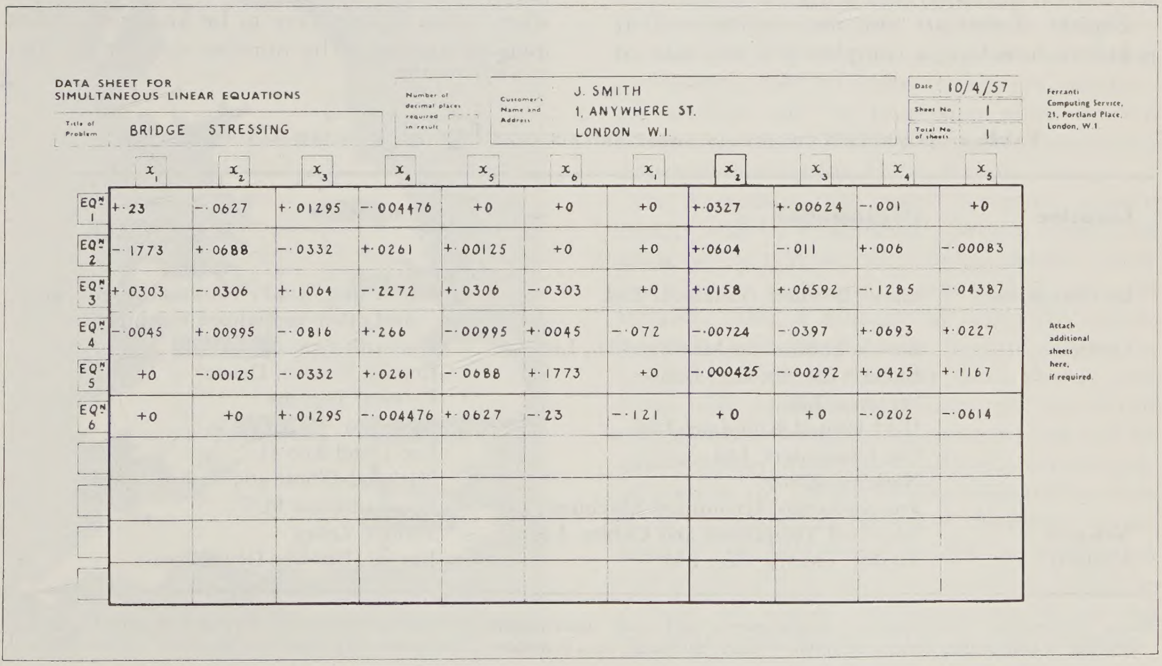
Facilities and charges vary. The basic procedure is for the customer to hire time on the computer and, where possible, to make use of a programme that is already written. When a programme exists, all that needs to be done is to supply the data relating to the particular problem. Often the data can be entered on standard forms, which makes their translation into the computer input-medium easier. These standard forms exist for many jobs like frame-stressing, pipe-stressing, optical-ray tracing, transport and mixing problems.

Besides programmes for the solution of standard problems "subroutines" are also available. A subroutine is a short programme devised to perform a particular calculation that is required repeatedly. Such calculations are the derivation of square and other roots or trigonometrical values as, for instance, sines, cosines and tangents. Use of these subroutines in a master programme simplifies the task of writing the programme.

Therefore, the user has at his disposal at the computing centre a fund of experience in the form of complete programmes, a library of subroutines and expert advice on computing techniques. It must be emphasized that the value of a computer lies as much in the programmes that have been written for it as in the machine itself.

Two main factors that affect the cost of the service are the speed of the machine and, of

*Fig. 3. Where programmes already exist that are of general use, a standard form is produced on which the customer can enter the data relating to his problem—such as, for example, this structural calculation*



DATA SHEET FOR
SIMULTANEOUS LINEAR EQUATIONS

Title of Problem: BRIDGE STRESSING

Number of decimal places required in result:

Customer's Name and Address:
J. SMITH
1, ANYWHERE ST.
LONDON W.1.

Date: 10/4/57
Sheet No: 1
Total No of sheets: 1

Ferranti
Computing Service,
21, Portland Place,
London, W.1

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EQ$^{N}$ 1 | +·23 | −·0627 | +·01295 | −·004476 | +0 | +0 | +0 | +·0327 | +·00624 | −·001 | +0 |
| EQ$^{N}$ 2 | −·1773 | +·0688 | −·0332 | +·0261 | +·00125 | +0 | +0 | +·0604 | −·011 | +·006 | −·00083 |
| EQ$^{N}$ 3 | +·0303 | −·0306 | +·1064 | −·2272 | +·0306 | −·0303 | +0 | +·0158 | +·06592 | −·1285 | −·04387 |
| EQ$^{N}$ 4 | −·0045 | +·00995 | −·0816 | +·266 | −·00995 | +·0045 | −·072 | −·00724 | −·0397 | +·0693 | +·0227 |
| EQ$^{N}$ 5 | +0 | −·00125 | −·0332 | +·0261 | −·0688 | +·1773 | +0 | −·000425 | −·00292 | +·0425 | +·1167 |
| EQ$^{N}$ 6 | +0 | +0 | +·01295 | −·004476 | +·0627 | −·23 | −·121 | +0 | +0 | −·0202 | −·0614 |
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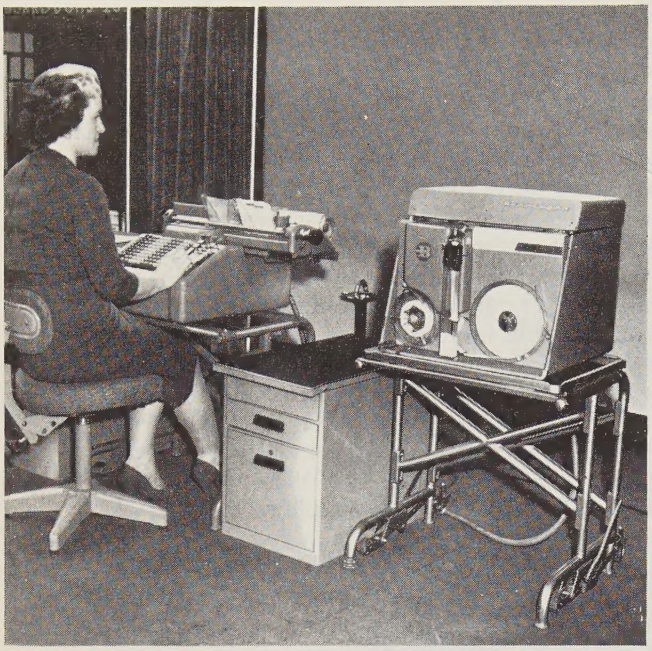


*Fig. 4. A Burroughs accounting machine connected to a tape punch. Information entered on the keyboard is automatically reproduced in the tape*

course, the extent of the service given. Obviously, a machine must cost more to hire if it can do more work in a given time. Also, the more programming that is done for the customer, the more he must pay. Therefore, although charges range from £5 to £75 an hour—£40 and £50 are typical—a direct comparison between services cannot easily and fairly be made.

Figures of cost are also meaningless until it is known how long a complete job will take to run on a particular computer. Often it is not realized that many jobs are completed in a matter of minutes, and so are quickly and cheaply handled. Many jobs hitherto performed on desk machines can be completed with greater accuracy and in far less time on a computer.

As soon as a computer has finished one calculation, it is entirely free for the next. For example a small set of simultaneous equations can follow directly after an analysis of sales statistics. Several people, therefore, can use a machine one after the other. As many as 40 or 50 people—30 is a fair average—might use the computer for as many different jobs during the course of one day.

A computing service need not be local. Sometimes, it is economic to use a service abroad. For example, on a number of occasions it has been worth while for a representative of a Swedish aircraft company to fly from Sweden to London to run a programme taking only one hour on a computer. If it is not profitable for a representative to go, data can either be physically transported by post, or transmitted over a teleprinter-line. Where data are transmitted by teleprinter a thorough checking system is essential to prevent errors.

One system devised for sending data is worth describing, as increasing use will be made of such methods in the future. The system is for commercial work and is based on a ledger posting machine fitted with a paper tape perforating attachment. Consider an example where sales figures have to be analysed. Sales invoices are coded by number to indicate sales

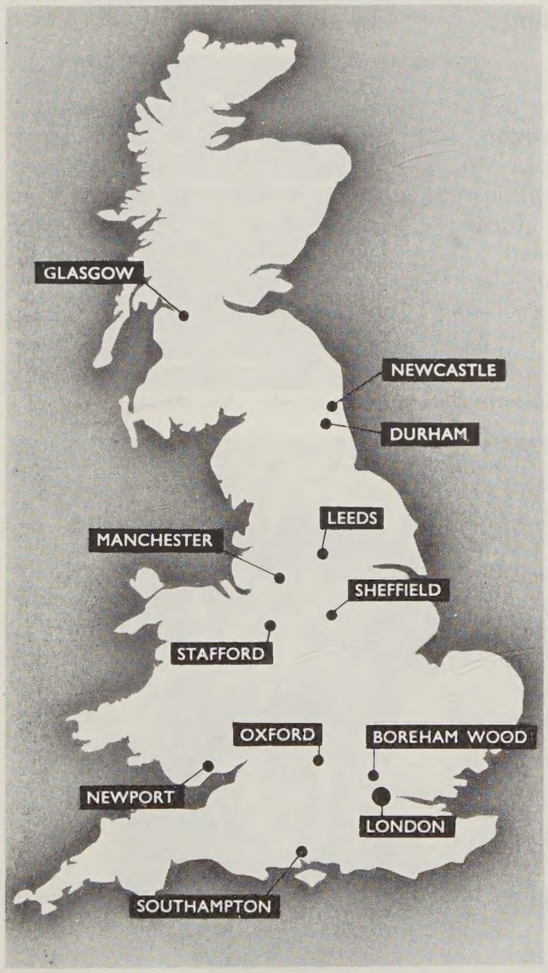
**Table 1**—COMPUTING CENTRES IN GREAT BRITAIN OPERATED BY COMPUTER MANUFACTURERS

| **Location** | **Organization** | **Computers** |
|---|---|---|
| Borehamwood | Elliott Brothers (London), Ltd. | Elliott 402, 402F, National-Elliott 405 and other specialized machines |
| London | British Tabulating Machine Co., Ltd. | Hollerith type 1201 |
| | English Electric Co., Ltd. | English Electric Deuce |
| | Ferranti, Ltd. | Ferranti Pegasus |
| | IBM United Kingdom, Ltd. | IBM 650 |
| | Leo Computers, Ltd. | Leo I and Leo II |
| | National-Elliott | National-Elliott 405 |
| | Powers-Samas Accounting Machines, Ltd. | Powers-Samas PCC |
| Newport | Standard Telephones and Cables, Ltd. | Stantec Zebra |
| Stafford | English Electric Co., Ltd. | English Electric Deuce (two) |

Many universities, Government establishments and trade associations also possess electronic digital computers and can provide a computing service to outside users, although in a number of instances only restricted facilities are available area and product type. A clerk then adds the codes, quantities and values on each invoice on a listing machine and writes a check sum at the foot.

Next, the invoices are posted to the sales ledger on the accounting machine. While the normal accounting operations are performed, a punched paper tape is produced containing the details of each item invoiced and the check sum. The ledger is posted, a statement is prepared and the punched paper tape is produced in one operation. As the items are punched the accounting machine produces a check sum and, if this sum does not agree with that entered on the invoice, the machine automatically indicates an error and the operator repeats the invoice. If the operator realizes that a mistake has been made before the end of the invoice is reached, she can punch an error code in the paper tape and start the invoice again.

*Fig. 5. Geographical location of computing centres throughout Great Britain. Many of these centres are at universities*



The information on the punched tape can then be transmitted over a teleprinter line to the computing centre. Experimental transmissions of data have shown long periods of error-free operation interspersed with occasional crops of errors. The accounting machine punched tape is fed into a tape reader and the information transmitted is received at the centre and recorded in punched tape.

**Computer check sum test**

As the data on the punched tape are entered into the computer, the check sum is again verified. Should a check sum fail this will indicate the beginning of possibly a sequence of incorrectly transmitted data. Further invoices are read until one is reached which passes the check sum test. The batch of invoices known to contain erroneous information is then retransmitted and they are again subjected to the check sum test. In this way it is possible to confirm that all the data transmitted are correct.

One interesting point about existing computer centres in Britain is their geographical position. Roughly speaking, they are either in provincial cities or in the West End of London. As yet, there is not one centre in the City of London, where a considerable demand might have been expected. Partly, the reason is that most of the work done so far has been of a scientific or technical nature, as has most of the work performed by privately operated computer installations. Now that computers are being increasingly used for commercial work, computing services will be processing more routine commercial data. Table 1 shows the computing centres established in Great Britain.

It is certain that more computer service centres will be established. Several important areas of the country are not yet served: there is only one centre in Scotland and none in Ireland. Also, a number of computer manufacturers who do not now operate centres in London intend to establish them shortly and those with established services will no doubt extend them. In addition, more centres will be established at universities and technical colleges. At present, the demand seems unlimited in view of the increasing awareness of the nature of the services available, coupled with the realization that such centres offer an excellent training-ground, in which experience can be gained before an organization installs its own computer.

# Automatic reading

**Boots Pure Drug Company Ltd. are to install the first commercial model Solartron ERA Automatic Reading Machine in order to extract information direct from printed cash-register tally rolls**

The first commercial model of the Solartron ERA automatic reading machine can

*read information directly from a standard commercial document, such as a cash-register tally roll;*

*identify the numbers* 0 *to* 11, *the fraction* ½, *the plus sign and eight specified letters;*

*read at* 200 *to* 300 *characters a second with an error rate considerably better than* 1 *in* 1,000,000*;*

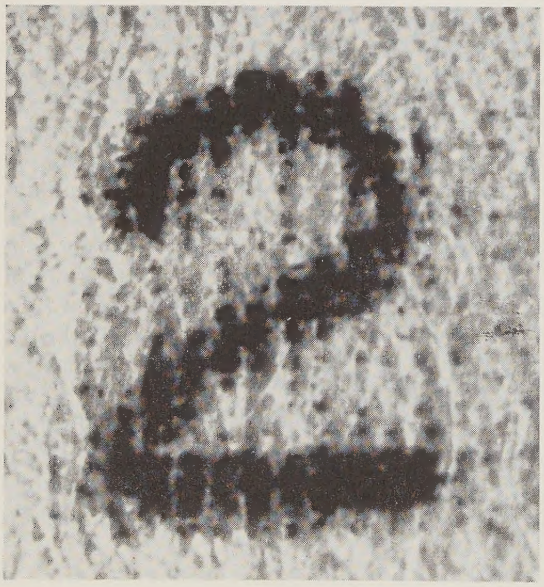
*be used to operate a sorter, tape or card punch or feed a computer.*

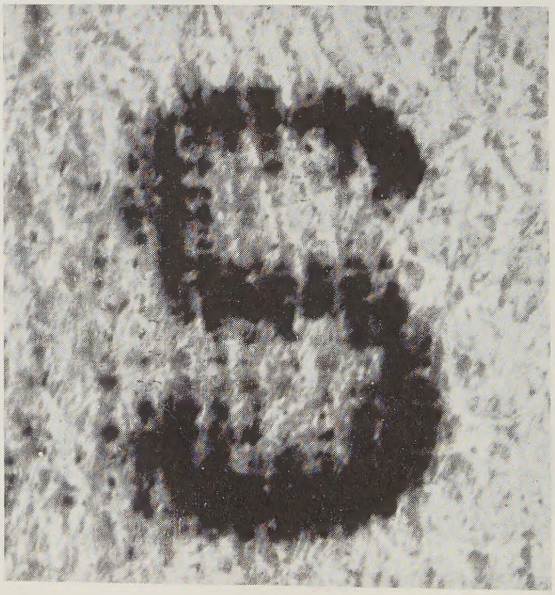
As yet, such machines cannot read handwriting, though some experimental work is being conducted on this problem.
It would be helpful if the commercial world could standardize a type-fount for use on all documents which later might have to be read by machine.

To transcribe information from typed, printed or handwritten documents on to punched cards, punched tape or magnetic tape by manual methods in order that this information can be entered into an automatic data processing system is a slow and exacting procedure. In itself, transcription is not a difficult task, but it does mean that human operators are required to perform what is intended to be an entirely automatic operation. Of greater importance, however, is the certainty that occasional errors will be made during the transcription sequence.

Ideally, the required information should be read directly from the original document and supplied straight to the computer or data processing system. Solartron Electronic Group

*Figs.* 1 *and* 2. *Magnified images of typical second carbon copy characters as produced by a typewriter. Note the blurred outlines*





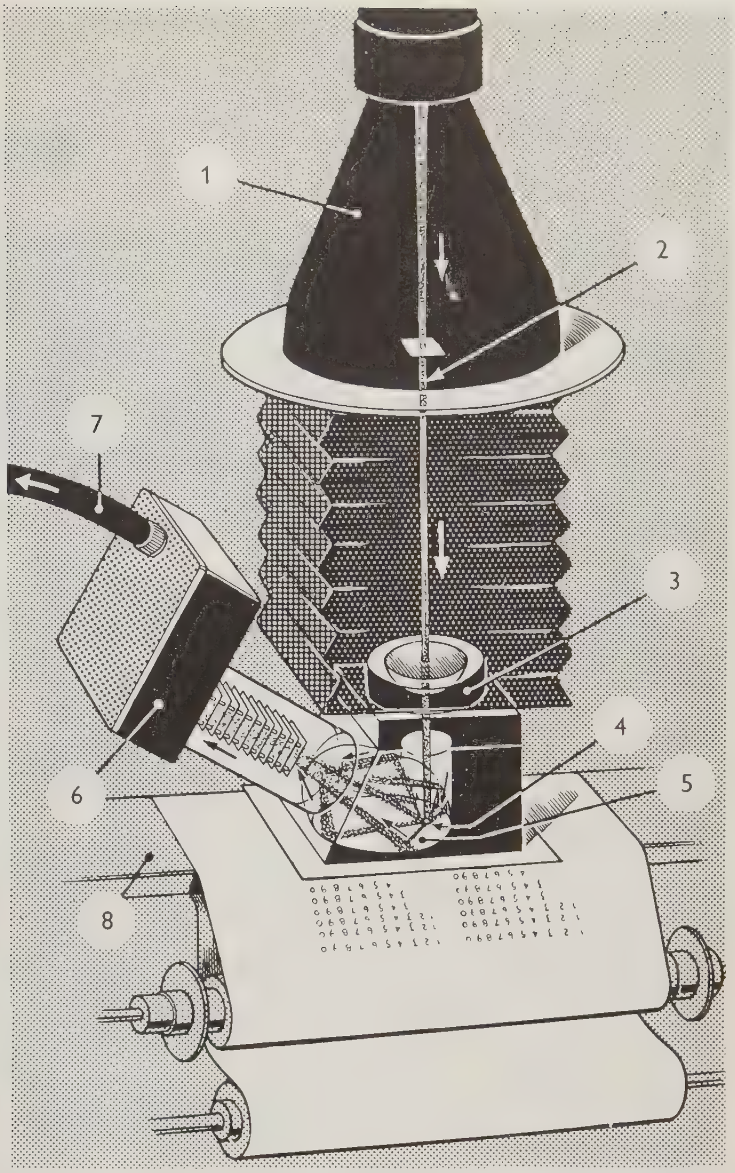
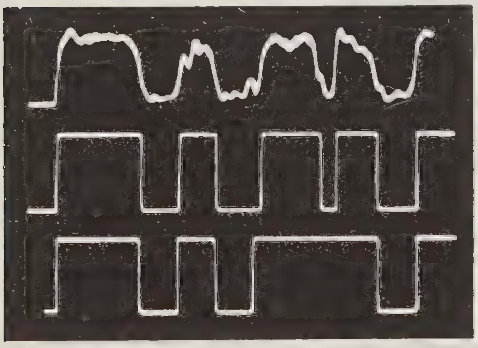


*Fig. 3 (right). Reading head of the prototype ERA.* **1,** *Cathode-ray tube;* **2,** *Light beam;* **3,** *Lens focusing light spot on character;* **4,** *Character being read;* **5,** *Parabolic mirror focusing light reflected from paper on to photomultiplier;* **6,** *Photomultiplier;* **7,** *Output signal to character identification circuits;* **8,** *Typewriter carriage. The light spot traverses the character. Light reflected from the paper into the photomultiplier causes the latter to emit an electrical signal that represents the character observed*

*Fig. 4 (below). The varying electrical signal emitted by the photomultiplier is shown at the top. Next is the signal after it has been simplified by clipping and, finally, the "cleaned" signal free from errors*



Ltd.,* have built an Electronic Reading Automaton (known as ERA) that performs such a function and consequently eliminates the need for transcription. A pilot model of this machine has been in operation since February, 1957. This machine can identify any of the typed numerals 0 to 9 and reads them at the rate of 120 characters a second.

The first commercial model has an extended reading range. It can identify the numbers 0 to 11, the fraction ½, the plus sign and eight specified letters. The numbers 10 and 11 are recognized as single values where they occur in the pence column of an account. With later production models of ERA the reading range will be extended and it is expected that, eventually, the reading of handwritten marks and numerals will be possible.

In the first commercial machine the reading speed has been increased to between 200 and 300 characters a second. The precise speed depends largely upon the format of the document. With a cash-register tally roll the average is 250 characters a second.

As stated, the first commercial machine is to be used by Boots Pure Drug Company Ltd. to

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*Solartron Electronic Group Ltd., Thames Ditton, Surrey

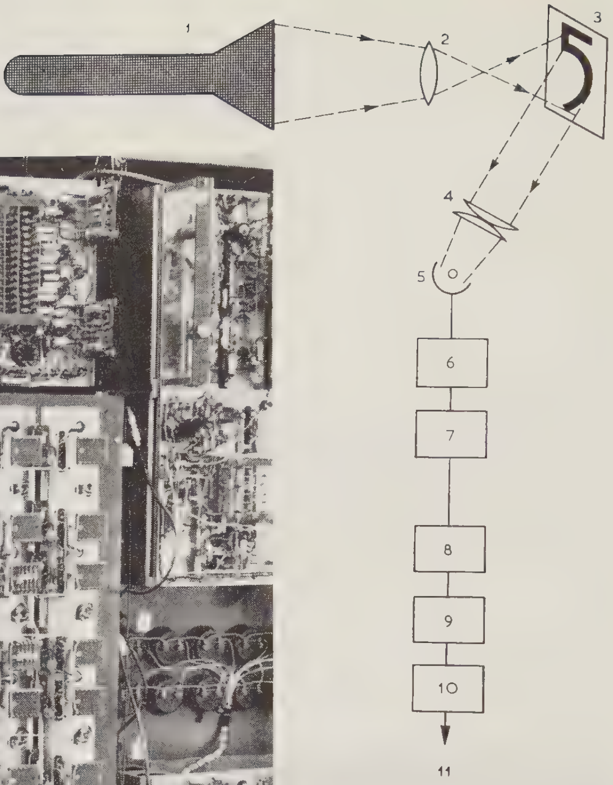


*Fig. 5. A diagram showing the sequence of operation.* **1,** *Cathode-ray tube;* **2,** *Lens focusing light on character;* **3,** *Character;* **4,** *Optical system focusing reflected light on photomultiplier;* **5,** *Photomultiplier;* **6,** *Clipping circuit;* **7,** *Integrating and pulse width discriminator;* **8,** *Row and column matrices (100-way switch);* **9,** *Information store (100 items);* **10,** *Logic circuits;* **11,** *Output to computer. The continuous electrical signal from the photomultiplier is simplified by the clipping circuit and errors owing to dirt are removed by the pulse width discriminator. The cleaned signal is divided into 100 sections and the character automatically recognized*

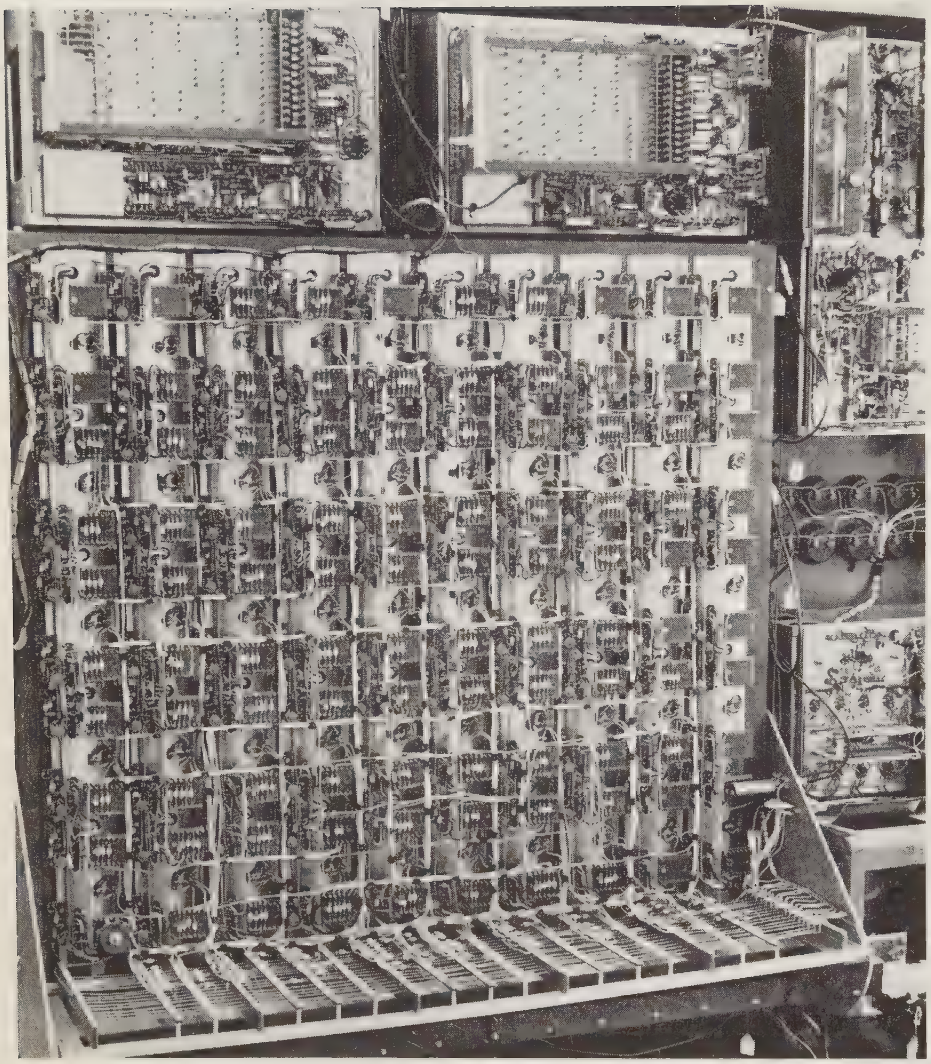
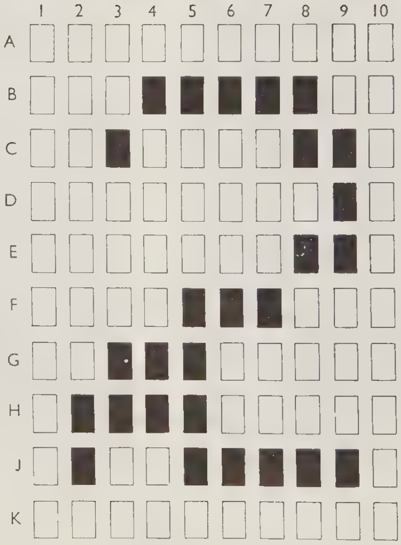


*Fig. 6 (above). The hundred cells of the information store of the prototype machine*

*Fig. 7 (right). Typical pattern created in the information store by the figure 2*



|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| A | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| B | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ | □ |
| C | □ | □ | ■ | □ | □ | □ | □ | ■ | ■ | □ |
| D | □ | □ | □ | □ | □ | □ | □ | □ | ■ | □ |
| E | □ | □ | □ | □ | □ | □ | □ | ■ | ■ | □ |
| F | □ | □ | □ | □ | ■ | ■ | ■ | □ | □ | □ |
| G | □ | □ | ■ | ■ | ■ | □ | □ | □ | □ | □ |
| H | □ | ■ | ■ | ■ | ■ | □ | □ | □ | □ | □ |
| J | □ | ■ | □ | □ | ■ | ■ | ■ | ■ | ■ | □ |
| K | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |

read cash-register tally rolls. In these, each line consists of nine characters—two letters and seven numerals. The tally rolls are fed through the reading head at approximately 5in per second, which gives a reading speed of 27 lines per second. From ERA the output will pass to a special-purpose computer. The complete system is to be used for cash control and sales analysis work.

The installation of this reading machine is the first step to be taken by Boots towards creating an integrated data processing system at their Nottingham offices. When complete, the system will improve the efficiency with which the company's 1,300 shops can be administered.

Concurrently with the introduction of the reader, 1,000 specially modified cash registers are being built by the Norwegian company Jorgen S. Lien Industrier, of Bergen. Ultimately, 6,000 of these registers will be needed to equip all 1,300 branches. The registers are being fitted with a special type-fount to simplify the task of automatic reading (Fig. 11, page 15).

## Development work

At present development work on the Solartron ERA is being concentrated on reading long, narrow continuous documents. Work on the reading of larger documents is proceeding, but the problems associated with the paper-feed mechanisms are complex.

Among the types of work ERA could perform where information is printed on documents of tally roll style are the operation of card-punching units to record individual cash payments by customers for dividend payment purposes, the feeding of information for stock-control calculations in a large retail store selling fashion goods, or the rapid acquisition of raw data for statistical analysis from a recording roll attached to a ticket-issuing machine.

Extended trials have been completed with the pilot ERA and it is stated that, for a specified quality of print, the error rate—that is the number of times a figure has been incorrectly identified—is one in a million. With the first commercial machine it is expected that this will be reduced to one in ten million. As stated, the first commercial machine is to be used in an accountancy application, one in which accuracy of operation is imperative.

Obviously, recognition of printed characters is an exacting operation to perform automatically. Letters may be malformed, misplaced, overprinted, smudged, obscured or, in some other way, obliterated, and a certain amount of reasoning is needed to decide what letter or figure is intended. Because of this, most automatic reading machines made hitherto have not operated consistently.

For a reading machine to be of real worth in the business world it is essential that it should be able to operate from such a common business document as a typed second carbon copy. As can be seen in Figs. 1 and 2, the forms of such letters are blurred to a considerable extent. To overcome this problem and avoid ambiguity, ERA obtains considerably more information than would be needed to identify a crisply printed letter. One hundred bits of information are obtained by the pilot model ERA from each character observed and, by means of logic circuits, this character is then positively identified.

While the following description of ERA applies to the pilot model, only minor design changes have been made in the first commercial machine; the mode of operation is basically the same.

The eye of the machine is a scanning device which reads each character individually and in sequence. By suitable screening, all extraneous light is excluded from the region of the character being read. The actual scanning unit comprises a cathode-ray tube, an optical system and a photomultiplier. Light emitted by the fluorescent spot on the tube screen is focused by a lens to fall upon the area containing the character to be read. The light spot traverses this area following a ten-line rectangular pattern. A mirror system collects all the light reflected from the surface of the document and directs it upon the photomultiplier.

## Derivation of signal

Light reflected from the document varies in intensity according to the luminosity of the reflecting surface and causes the signal emitted from the photomultiplier to vary in a similar manner (Fig. 4). The continuous electrical signal generated by the photomultiplier is amplified and sent to a clipping circuit which emits signals at one of two signal strengths, depending upon whether the signal received from the photomultiplier is above or below a pre-set level. High signal strengths indicate that the scanning spot is traversing the white areas adjoining the character observed, while the low signal strengths represent the dark or printed form of the character.

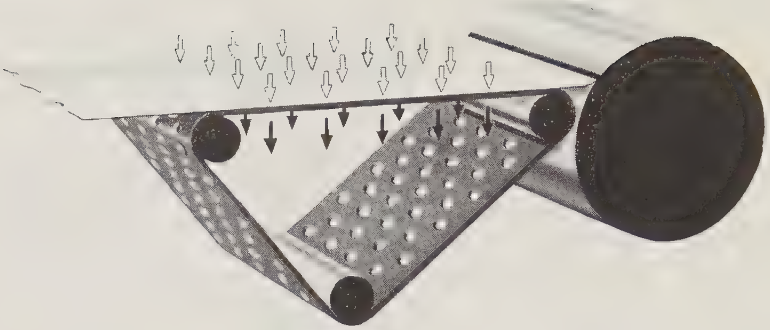
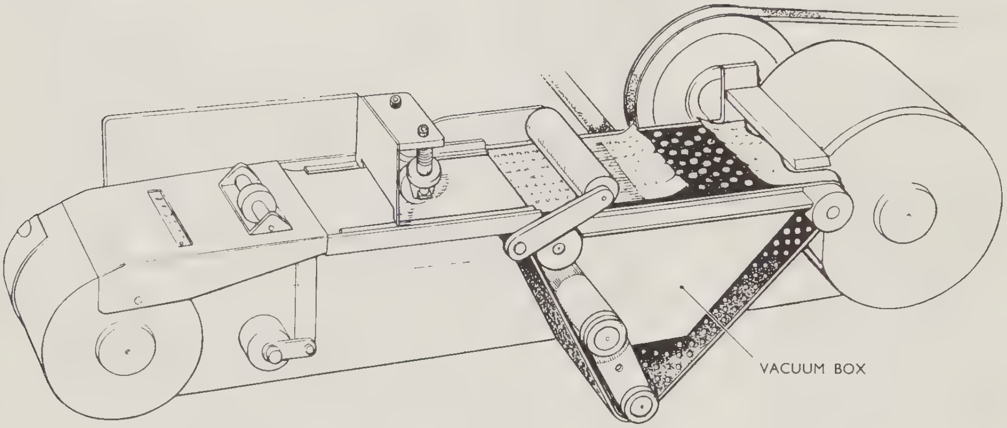


*Fig. 8. Mechanism for feeding continuous paper documents. A vacuum is created beneath the porous endless belt, thus causing the documents to adhere*



The signals from the clipper are then further modified to remove those portions created by the presence of dirt, or other small spurious marks on the document. This process is performed by an integrator and pulse-width discriminating circuit. Any pulse below a certain minimum width, such as could be caused by dirt or smudges around the character, or gaps within the character, is automatically eliminated by this circuit. The result is a final cleaned signal, ready to be sent to a read gate.

At this stage of the operation, an electrical signal of unique pattern will have been derived which represents the character read. Then, in order to identify the particular character, the signal has to be examined as an entity. The square-wave signal that has been derived is transmitted through the circuits as a continuous electrical signal—that is, it is transmitted in serial form. It is then divided into one hundred separate sections by row and column matrices, which may be considered as a hundred-way switch. These hundred sections, or bits, of information are then directed to and retained in an information store which consists of one hundred individual storage cells.

Because the signal is divided arbitrarily into one hundred sections, many of these sections

*Fig. 9. Arrangement of the first commercial model automatic reading machine to be installed by Boots Pure Drug Company Ltd.*

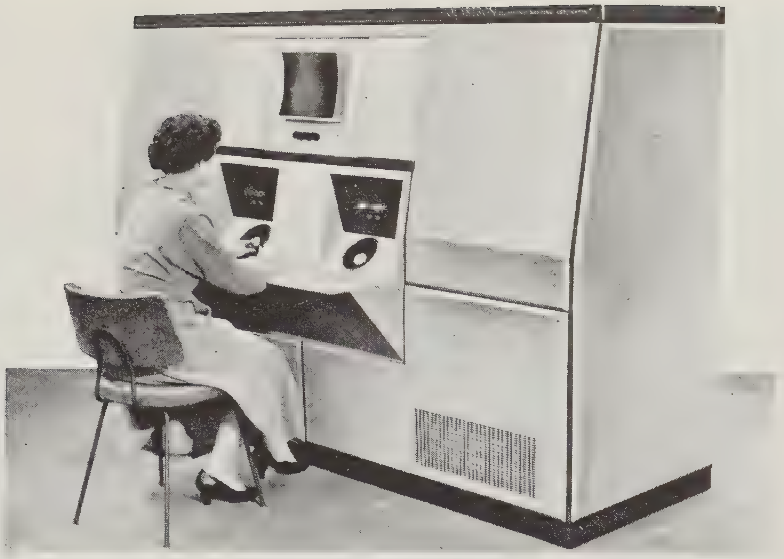


*Fig. 10. Section of one of the cash-register tally rolls*

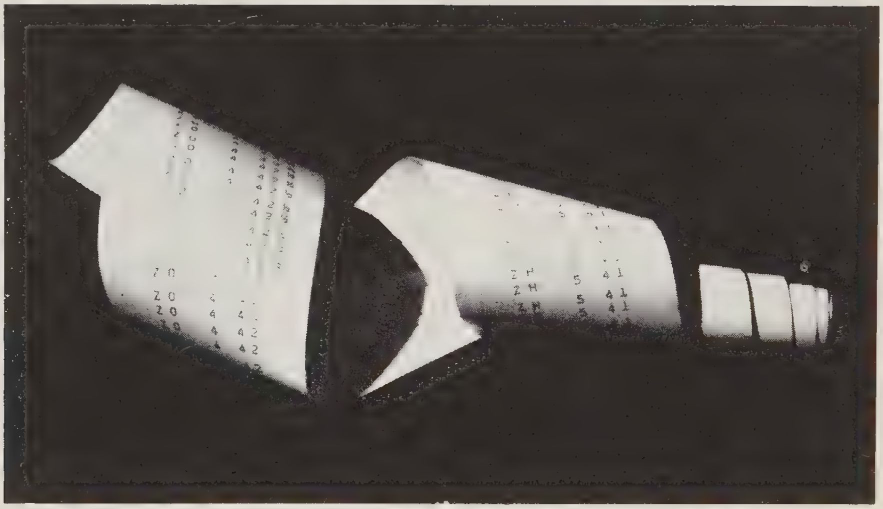
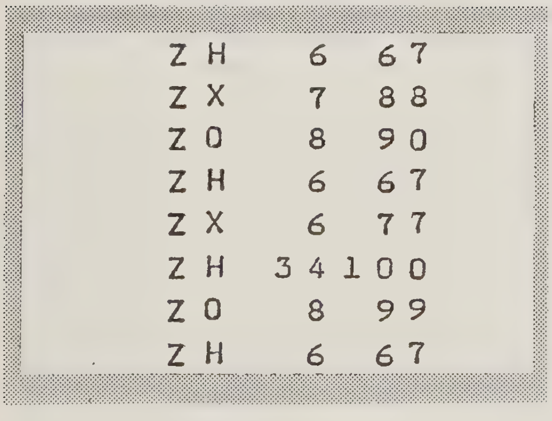


*Fig. 11. Facsimile of type font used on tally roll*



```
ZH      6   67
ZX      7   88
ZO      8   90
ZH      6   67
ZX      6   77
ZH  34100
ZO      8   99
ZH      6   67
```

will consist of a portion at the high signal strength level associated with a portion at the low signal strength level. Where this is so, a "rounding off" process is performed and the signal is identified as being predominantly either high or low, that is as representing either a basically white area or a basically black area. When all the information has been dealt with in this manner, the store will contain an idealized pattern of the character observed, in which each information cell is set to represent either a white or black increment. (Fig. 7.)

In the pilot model each information cell of the store is a flip-flop valve circuit. But in the first commercial machine an information cell consists of two magnetic core units. This alteration in the design was made primarily to reduce power consumption and to improve operational reliability. With one or other of the cores magnetized and its companion unmagnetized the binary characters, black or white, can be represented. If both cores, however, are simultaneously magnetized or unmagnetized it will mean that no information has been received during the reading scan or some other operational error has occurred, in which case the machine will cease to work and a fault will be indicated. This action prevents an incorrect interpretation of a character owing to a faulty circuit.

### Stored pattern

Each character of one particular form creates a typical pattern in the information store rather than an identical pattern. The reason for this is that the position of each character under the reading head can vary and, as a result, the disposition of the bits of information among the individual cells will also vary. Account has to be taken of this in the operation of the logic circuits.

Characters are identified by the logic circuits recognizing the pattern created in the information store. To take a typical example, if black is recorded in either cells B4 and B7, or in cells B3 and B6, and black is also entered in cells F6 and J7, but not in G9 or E3, the character is a 2 (Fig. 7). In practice, the "statements" are somewhat longer and more complex, but this is the principle.

As a result of the operation of the logic circuits, only one of a series of output wires will carry a signal and the particular wire energized will, of course, indicate the character read. This signal can operate a sorter, tape or card punch, or enter information directly into a computer store. Then the information stores are cleared automatically and the next character is read.

An important point is that each reading action involves two scanning sequences, but only during the second does character recognition, as described, take place. The first sequence centralizes the scan on the character and a twenty-line rectangular pattern is used for this purpose. A count is made of the number of lines traversed before the edge of the character is encountered. Similarly, a count is also made of the number of clear lines following the character. If these two counts are unequal the deflection circuits connected to the cathode-ray tube are energized in order to centralize the area of the scan on the character. Similarly, the vertical position of the character is assessed and any appropriate correction made. In this way, mis-alignment up to 50 per cent of character width or height can be accommodated. When the scan has been centred on the character the second, the recognition, scan is initiated with a ten-line pattern. No corrections can be made for angular mis-alignments but a certain latitude exists and characters can still be recognized provided that they are not displaced by more than 10 degrees.

The number of errors made by the pilot model has been mentioned, also the expected error rate of the later version of the machine. The figures referred to the actual number of times a character was incorrectly identified and the wrong output signal generated, not to the number of times a character could not be deciphered. The logic circuits are not forced to produce an output for each character presented for identification. Consequently, if a particular character is badly distorted or malformed, the logic circuits of the machine will not recognize it and the character will not be identified. Normally, when this happens a signal draws the operator's attention to the fact and the line of the document in which the unidentified character appears is marked. Hence, at the end of a reading sequence the operator can quickly see which lines of the document require attention.

### Overstamped type

Another important feature is that the machine can read type which has been partially obscured by being overstamped. Provided that the overprinted impression is less dense than the type, the clipping level can be adjusted so that the overprinted areas are identified as being, in effect, white. True information concerning the character will, therefore, be transmitted to the logic circuits. Where the overprinting is of the same density as the character the spurious signals generated cannot be filtered out in this way and the logic circuits must perform the identification unaided. It is because it permits heavily obscured characters to be positively identified that the amount of information entered in the information store is so large—the 100 bits per character that have been mentioned earlier in the article.

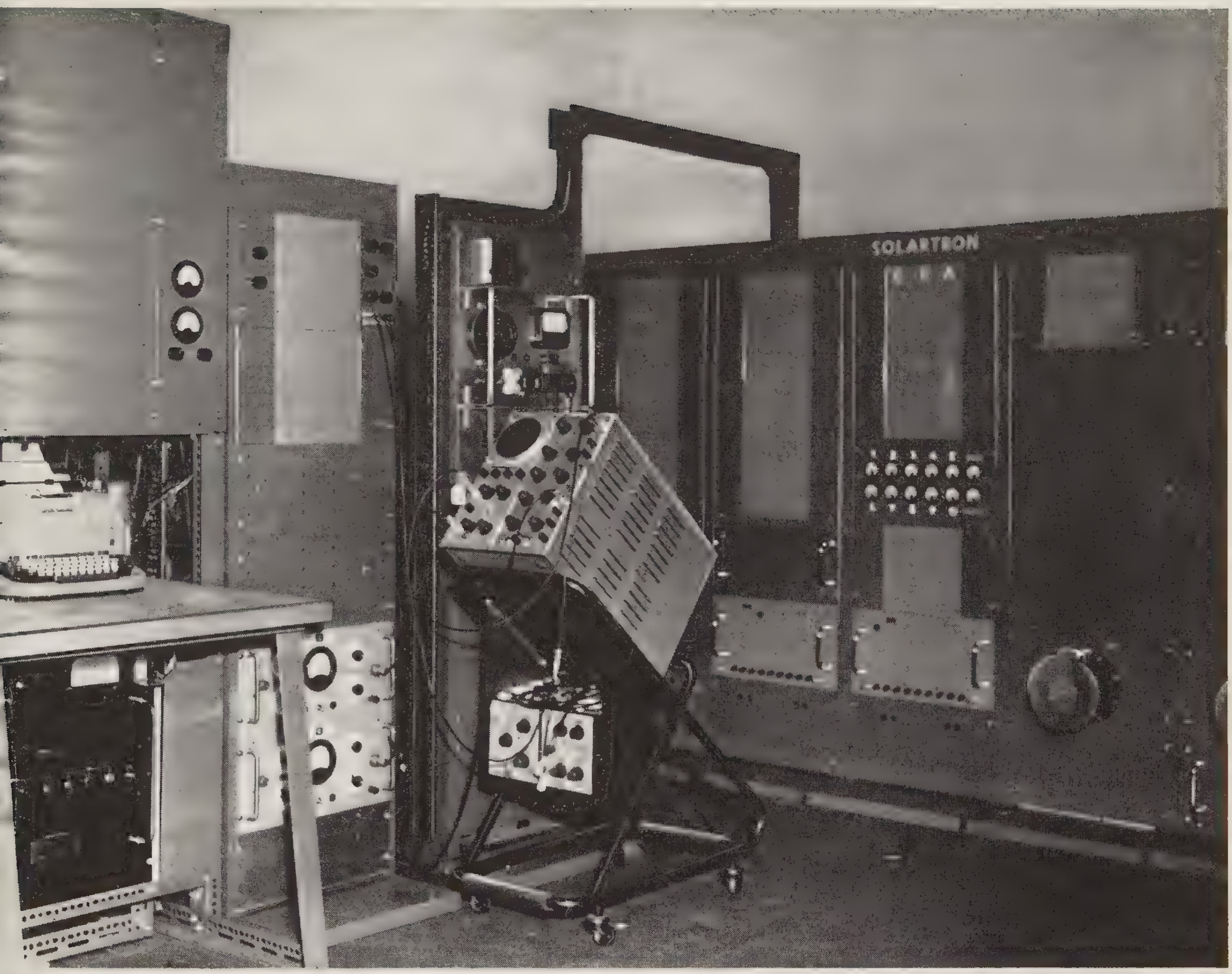


*Fig. 12. Prototype Solartron ERA automatic reading machine that can identify the numerals* 0 *to* 9 *at the rate of* 120 *a second*

A mechanical feed to suit the particular type of document to be read is fitted to the reading machine. The pilot model reads characters on a document wound over the roller of an electric typewriter. The document is traversed automatically by the normal carriage-shift and line-advance mechanisms. For reading continuous paper documents, such as cash-register tally rolls, the paper is fed past the reading head on an endless and continuously moving porous belt. A vacuum created on the underside of the belt causes the paper to adhere.

Where the length of the line to be read is short (not greater than, say, 3in) no mechanism is needed to traverse the document laterally, the deflection circuits of the cathode-ray tube being able to move the scanning spot over this amount.

The development of character reading machines represents a considerable and potentially valuable advance, especially for commercial data processing work. One of the major difficulties associated with this work is connected with the type styles used. While the machine can read most printed or typed characters, a slightly different logic is required to identify different type founts. It would be advantageous, therefore, if in the commercial world there could be general agreement on a type fount to be adopted as standard for all documents which later may have to be read by machine.

# THE UNIVERSAL LANGUAGE OF COMPUTING

**A simple explanation of binary numbers, binary arithmetic and decimal binary codes**

Most people are so accustomed to counting in the decimal system that often it comes as a surprise to learn that alternative systems exist. In fact, a wide variety of counting techniques are used in everyday life, especially in Great Britain where we are firmly attached to our curious and unique scales of measurement, such as, 12 inches equal one foot, three feet equal one yard and 1,760 yards equal one mile.

However, while the complexities of our own measuring systems do not worry us, when machines are required to perform calculations it is better to adopt a simpler notation—in fact the simplest of them all—the binary notation. Binary means that the system only possesses two numerals, 0 and 1, instead of the ten, 0 to 9, of the decimal system. The popularity of the binary notation for electronic computing machinery rests entirely on this attribute—that only two numerals are required—consequently, the computing circuits can be built up of relatively simple two-state counting units. When set in one condition the counting unit represents 1 and when set in the alternative condition the unit represents 0.

Although binary as an adjective is unfamiliar, the method of counting in this way does not involve any ideas that differ from those already used when counting in the decimal system. Consequently, binary counting is just as easy to understand and perform.

In the decimal system, of course, all numerical values are expressed by sequences of the ten decimal digits 0 to 9, while, as has already been stated, with the binary system all numerical values are portrayed by sequences of the two binary digits* 0 and 1. When counting in any notation the only rule to remember is that when 1 is added to the digit possessing the highest value in the particular system, the numeral reverts to 0 and a 1 is carried into the column on the immediate left. For example, in the decimal system 9 + 1 equals 0 carry 1, and this is recorded as 10. In an identical manner, when counting in the binary scale where the numeral possessing the highest value is one, 1 + 1 equals 0 carry 1, and this is written down as 10.

The binary number 10, of course, does not equal the decimal number 10 because the numerical "weight" of the columns in the two numbers is different. With the decimal system a number column on the immediate left of another possesses a value that is ten times greater. In a binary system a number column on the immediate left of another possesses a value that is only two times greater. To clarify these ideas a count extending from 0 to 12 is given below showing the decimal number and the equivalent binary number.

| Decimal system | Binary system | The conversion step by step |
|---|---|---|
| 0 | 0 | 0 = 0 |
| 1 | 1 | 1 = 1 |
| 2 | 10 | 2+0 = 2 |
| 3 | 11 | 2+1 = 3 |
| 4 | 100 | 4+0+0 = 4 |
| 5 | 101 | 4+0+1 = 5 |
| 6 | 110 | 4+2+0 = 6 |
| 7 | 111 | 4+2+1 = 7 |
| 8 | 1000 | 8+0+0+0 = 8 |
| 9 | 1001 | 8+0+0+1 = 9 |
| 10 | 1010 | 8+0+2+0 = 10 |
| 11 | 1011 | 8+0+2+1 = 11 |
| 12 | 1100 | 8+4+0+0 = 12 |

Considering this question of the "weight" to be associated with the position occupied by a digit in a number, the decimal number 1908 represents $(1\times1000) + (9\times100) + (0\times10) + (8\times1)$ which, of course, equals $(1\times10^3) + (9\times10^2) + (0\times10^1) + (8\times10^0)$. This presentation of a decimal number emphasizes the point made previously that a number column on the

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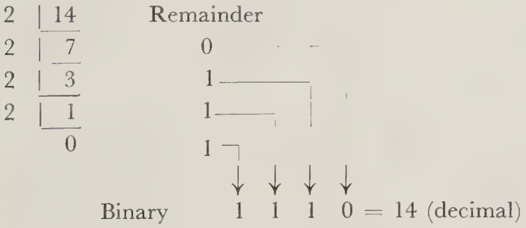
*It is now common practice to refer to a binary digit as a bit. This is possibly a contraction of the phrase **bi**nary digi**t**.

immediate left of another possesses a value that is ten times greater. (Incidentally in mathematics any number raised to the power 0 such as $10^0$ is always equal to one, i.e. in the example just quoted $8 \times 10^0 = 8$.)

Remembering this fact and that for the binary notation the difference in "weight" existing between adjacent columns is two, it is easy to convert a binary number into the equivalent decimal number. For example, the binary number 1110 represents $(1 \times 2^3)+(1 \times 2^2)+(1 \times 2^1)+(0 \times 2^0)$ which equals $(1 \times 8)+(1 \times 4)+(1 \times 2)+(0 \times 1)$ and totals 14. Binary number 1110 therefore is numerically equal to decimal number 14.

It is equally easy to translate a decimal number into a binary number by a similar, simple drill. The decimal number is divided repeatedly by two and this is continued until two "won't go." What is left over from the individual divisions—the remainders—arranged *in a line from right to left*, in the order in which they were obtained, is the required binary number.

To convert 14 into a binary number, it is divided by 2. The answer is 7, and the remainder from this division is 0. This 0 goes on the extreme right of the binary number being derived. Now 7 is divided by 2: the answer is 3 with the remainder 1. Continuing: 3 divided by 2 is 1 and again the remainder is 1. This final figure 1 divided by 2 "won't go," leaving a remainder of 1. All the remainders arranged in the order they were obtained from right to left become 1110. Hence 1110 in binary notation is numerically equal to 14 in the decimal system. Presented in pictorial form this calculation becomes:



Up till now, only whole numbers have been considered, but fractional values can also be represented in the binary notation. The fractional portion of a number is divided from the rest by a full point. In the decimal system, of course, this point is referred to as the decimal point and the equivalent point in a binary number is called the binary point. The "weight" to be attributed to a binary numeral following the binary point obeys the same rule as before–a number column on the immediate left of another possesses a value that is two times as great. Since we are working away from the decimal point it would be more convenient to reverse this expression and say instead—a number column on the immediate right of another possesses a value that is half that of its predecessor.

A binary fraction can be readily converted into a decimal fraction once the equivalent decimal values of the number columns following the binary point are known. These values can be assessed quickly. Starting from the column on the immediate left of the binary point, which has a value of 1, the first column on the right of the binary point has a decimal value that is half this—0·5. Continuing the process of halving the value for each succeeding column, the second column after the binary point has an equivalent decimal value of 0·25, the third column 0·125, the fourth 0·0625 and so on. Thus the binary number 1·1011 is equivalent to the decimal number $1{\cdot}0 + 0{\cdot}5 + 0 + 0{\cdot}125 + 0{\cdot}0625 = 1{\cdot}6875$.

It can be seen from this description that the complete range of numerical values can be represented in binary notation equally as well as in the decimal notation. Also, as stated earlier, all the normal arithmetical operations can be performed with binary numbers according to the accepted rules of arithmetic.

Below is an example of addition. The equivalent binary and decimal calculations are performed side-by-side to illustrate the similarity of the procedures and to confirm that the same numerical answers are always obtained. Bear in mind that in binary addition 1 + 1 equals 0, carry 1.

| Binary | | Decimal | |
|---|---|---|---|
| 1011 + 11 = | 1011 | 11 + 3 = | 11 |
| | 11 | | 3 |
| | 1110 | | 14 |

The reverse procedure, subtraction, can be performed equally easily if the rules are remembered. In a decimal calculation when, say, a 6 in one column has to be subtracted from 0, for instance 20 — 6, a 1 is brought back from the column on the left and the subtraction is now 10 — 6 equals 4. And the tens digit 2 has of course been reduced to 1, so the complete answer is 14. In the same way when 1 is to be subtracted from 0 in a binary number, a 1 has to be brought back from the column on the left, reducing it to 0, and the subtraction is now 10 — 1 which equals 1.

$$\begin{array}{rr} \text{Binary} & \text{Decimal} \\ 1110 - 1011 = 1110 & 14 - 11 = 14 \\ 1011 & 11 \\ \hline 11 & 3 \end{array}$$

Rules for binary multiplication are more immediately obvious as the calculation is handled exactly as if two decimal numbers consisting of 0's and 1's were being multiplied together. Thus 111010 × 101 goes as follows:

$$\begin{array}{r} 111010 \\ 101 \\ \hline 111010 \\ 000000\phantom{0} \\ 111010\phantom{00} \\ \hline 100100010 \end{array}$$

Binary division is also a straightforward operation, carried out exactly as with decimals.

The disadvantage of the binary notation, or for that matter any notation other than the universally understood decimal, is that where human operators are required to monitor the calculating sequence, difficulties are encountered in recognizing numbers of high value. In many computing systems this disadvantage is overcome by performing all calculations using binary numbers, but decimal-to-binary and binary-to-decimal conversion is performed at the input and output sections of the equipment. Thus numerical information can be prepared and presented to the machine by an operator in the conventional decimal form; this is then automatically converted and the calculations are performed using the binary notation. Results are reconverted from binary into decimal before being printed and so the results produced are immediately intelligible to the operator.

Difficulties of recognition have also led to the evolution of hybrid numbering systems which are part-binary and part-decimal. These systems are known as decimal binary, or binary coded decimal. In these notations, binary digits are used to represent the ten decimal digits. A sequence of four binary digits is needed for this purpose. In the simplest and most straightforward of these decimal binary codes, the first ten binary numbers are used to represent the decimal digits from 0 to 9. The decimal number 749 would then be portrayed in the decimal binary notation by three separate groups of binary characters in this manner 0111, 0100, 1001. Other decimal binary codes used in computation are the 2421 code and the excess three code. The numbers by which the first code is identified refer to the value or "weight" to be attributed to the digit 1 when it appears in a particular position in the number code. In the binary excess three code, each decimal digit is represented by a binary group that is equal to the original decimal value plus three.

Examples of counting in these codes are given below:

| **Decimal code** | **Decimal binary code** | **2421 Code** | **Excess three code** |
|---|---|---|---|
| 0 | 0000 | 0000 | 0011 |
| 1 | 0001 | 0001 | 0100 |
| 2 | 0010 | 0010 | 0101 |
| 3 | 0011 | 0011 | 0110 |
| 4 | 0100 | 0100 | 0111 |
| 5 | 0101 | 1011 | 1000 |
| 6 | 0110 | 1100 | 1001 |
| 7 | 0111 | 1101 | 1010 |
| 8 | 1000 | 1110 | 1011 |
| 9 | 1001 | 1111 | 1100 |

Up till now the portrayal of numerical values only has been considered. In business data processing work, considerable quantities of alphabetical letters, of necessity, have to be handled. No arithmetical operations, of course, can be performed on such data, but it has to be included among the numerical data where items are identified by code letters and also when data are to be produced in print. For such purposes groups of binary digits can be used to represent all the alphabetical letters in much the same way as groups of binary digits are used to represent the ten decimal digits in the decimal binary code. An example of this appears in the article on the Xeronic printer on page 54 where a code composed of groups of five or six bits can be interpreted and the character or numeral each group represents is printed directly on to the appropriate form.

Of the many numbering systems possible, the principal ones in current use are the pure binary and decimal binary codes because they have proved to be the most suitable for automatic computing machines.

# How an electronic digital computer calculates

## An indication of the function of the various units of a computer and how arithmetical operations are performed

BY M. H. JOHNSON, B.SC.*

An electronic digital computer is a machine —a complex one it is true—but nevertheless a machine, with all the qualities and failings that this implies. Its principal virtue is that it can perform the simple arithmetical operations at fantastically high speeds. It can complete 3,000 additions a second, or 500 multiplications a second. These are average speeds by present-day computer standards, and computers are already being designed which can perform these calculations ten times as fast.

This ability to do arithmetical operations rapidly means that numerical calculations can now be completed in a matter of minutes that would previously have occupied several days. Consequently, as far as business data processing is concerned, operational facts and figures can be obtained concerning the functioning of a business or a factory in sufficient time for management to take effective action to correct any deviation from the pre-arranged plan. Also, with such rapid calculating facilities available, it is possible to tackle jobs that, in the past, were considered too large, therefore impracticable.

A computer consists, basically, of five units:— An input unit—used to enter data into the machine. An output unit—that records the results of calculations performed by the machine. Information stores—where all data are held while not actually being processed, or handled. Arithmetic units—in which calculations are performed. And a control unit—that co-ordinates all these various activities within the computer. Three basic types of document—punched paper tape, punched cards or magnetic tape—are used for entering data into a computer. Similar documents are also used for recording the answers produced by the computer or the results may be printed directly on the appropriate forms.

Obviously, it is not sufficient just to present data to a computer. Because it is a machine, instructions must be given on where the data are to be stored, when they are to be withdrawn from store, what calculations are to be performed on them, where the answers obtained are to be stored and, finally, how the answers are to be recorded by the output unit. These instructions must be given in intricate detail, in the correct sequence, and cover all possibilities that could arise during the calculation. The complete list of operating instructions is called a programme.

Computers are sometimes referred to as stored-programme machines. This means that the programme itself is entered into the computer and stored internally before any raw data upon which it is to operate are supplied. During operation, each instruction is taken from the information store in sequence and is sent to the control unit where it is interpreted to determine the next operation to be performed by the computer. Consequently, the pattern of a computing sequence is:—

1, obtain an instruction from the information store;
2, perform the instruction;
1, obtain an instruction from the information store;
2, perform the instruction;
1, obtain an instruction from the . . .

. . . and so on until the programme, and, in turn the computation, has been completed.

Numbers are shuttled to and fro between the arithmetic unit and the information stores. Answers, as they are derived, are recorded by

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*Mr. Johnson is with Ferranti, Ltd.

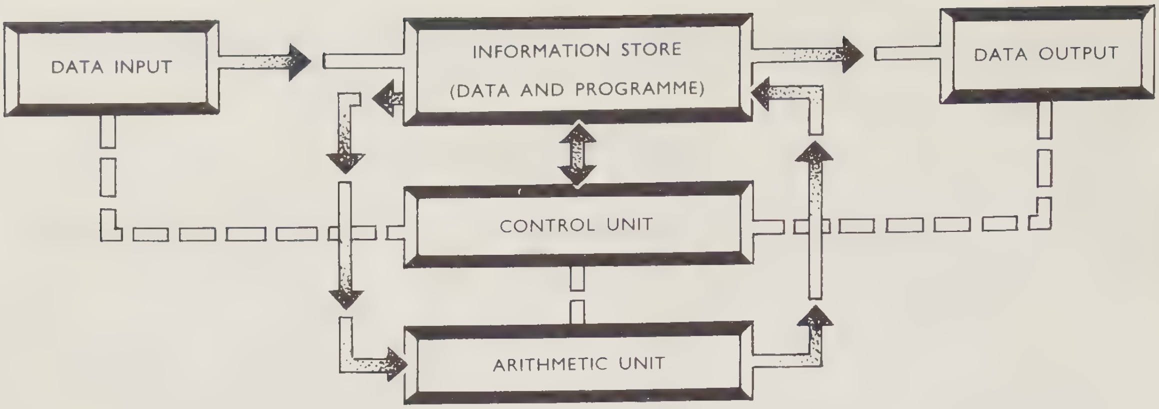


*Fig. 1. The five units of an electronic digital computer. Data flow between these units is indicated by the arrows; control functions are indicated by the broken lines*

the output units and new data, as they are required, are read by the input units. All these separate functions are initiated and synchronized by the control unit.

The flexibility of a computer—its ability to tackle a wide variety of tasks—rests on this ability to obey instructions stored within it. When charged with a programme, the computer, in effect, behaves as though it were a special calculating machine designed specifically to perform the particular computation for which the programme has been written. A computer differs from a calculator in that a calculator has to be either mechanically adjusted to perform a specific calculation or electrically adjusted by means of a specially wired connection board. Consequently, a calculator can neither perform such lengthy calculations, nor such intricate ones, nor is it so flexible in operation.

Means to perform calculations electronically only became possible as a result of techniques originally developed for radar. In radar a method had been discovered for generating electrical pulses of very short duration—of the order of one-millionth of a second—and electronic valves could be "opened" and "closed" by means of such pulses.

Use of such techniques for electronic computing became possible when means were discovered of representing numerical values by trains of electrical pulses arranged in specific patterns. And the other prerequisite was the discovery of a method of generating a third pulse train from two other pulse trains such that the numbers represented by these pulse trains bore a strict mathematical relationship with each other. From the moment a solution was found to these problems the development of the first electronic computers and, in turn, the creation of a new industry proceeded inevitably and, at times, with almost frightening speed.

Numbers, it has been stated, are represented in the computing circuits by patterns of electrical pulses. The pattern is constructed by the presence or absence of pulses appearing in a train of pulses of definite length. This is a binary system of representing numbers. In this respect, electronic computing has led to a revival of interest in a number system, the aesthetic appeal of which so captivated the great mathematician Leibnitz that he strenuously advocated its universal adoption. The characteristics of this notation have been fully discussed in the previous article, The Universal Language of Computing, to which, at this point reference could usefully be made.

There are two reasons why the binary numbering system is particularly useful in the design of an electronic digital computer. First, the storage and transmission of numbers in this form is extremely simple because the two digits —0 and 1—call merely for a two-state representation, for example, either a pulse or no pulse. Secondly, in the binary system the normal processes of arithmetic are very simple.

Rules of addition may be summarized as follows. Taking pairs of corresponding bits (binary digits, 0 and 1) from the two numbers to be added (starting, as with decimals, on the right) one proceeds step by step according to the following addition tables:—

| $a + b =$ | *a sum bit* and *a carry* (*forward*) *bit* | |
|---|---|---|
| $0 + 0 =$ | 0 | 0 |
| $0 + 1 =$ | 1 | 0 |
| $1 + 0 =$ | 1 | 0 |
| $1 + 1 =$ | 0 | 1 |

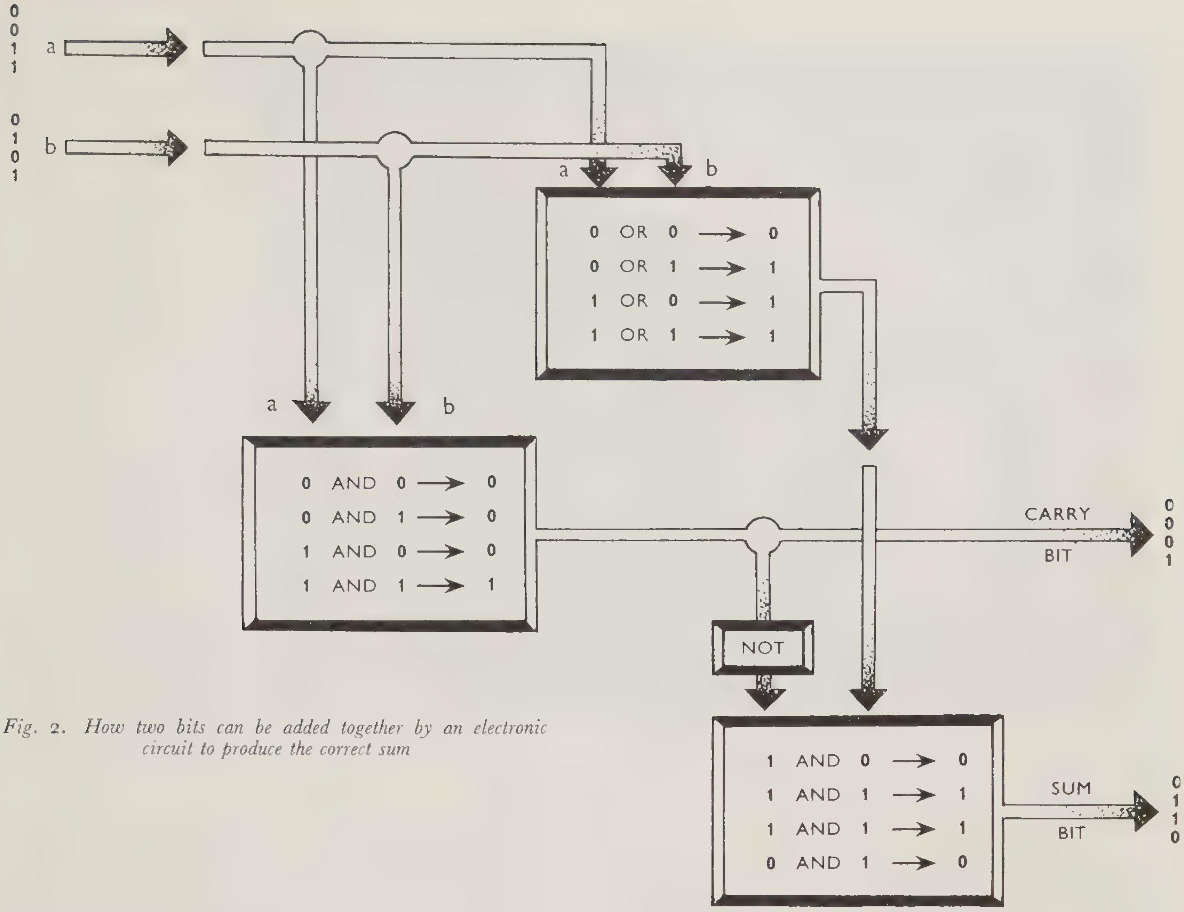


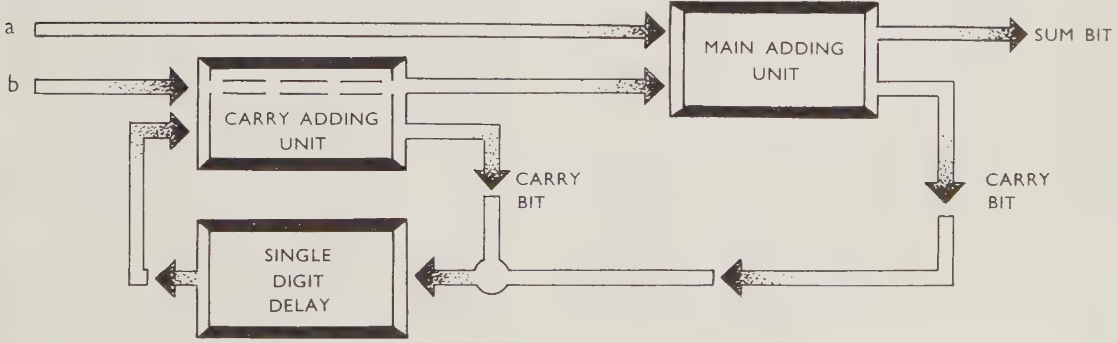
*Fig. 2. How two bits can be added together by an electronic circuit to produce the correct sum*

Unfortunately, there is no single simple electronic circuit which can produce the answers required—the sum bit and the bit to be carried forward—directly from the two original bits *a*, *b*. However, simple, compact and reliable electronic valve or transistor circuits can be built which perform three allied operations, described as *and*, *or*, *not*, and these can be interconnected to produce the required answers. First, the meaning of *and*, *or*, *not* must be explained. In the *and* operation, two bits *m*, *n* are combined by an electronic circuit to give a third bit *x* according to the following table:—

| *m* | *n* | *x* |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

That is to say, *x* is 1 if, and only if, both *m* and *n* are 1's. In all other cases *x* is 0.

*Fig. 3. Diagram of circuit that adds two numbers, transmitted as coded trains of electrical pulses, to produce the correct numerical answer in the form of a third pulse train*



In a similar fashion, with the *or* operation two bits *m*, *n* are combined by an electronic circuit to give a third bit *x* according to the following table:—

| *m* | *n* | *x* |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

Here *x* is 1 if, and only if, either *m or n* is 1.

By the *not* operation is meant the simple replacement of a bit by its opposite—all 1's become 0's and all 0's become 1's.

### Addition by electronic circuits

With these three types of circuit arranged in a special sequence it is possible to add *a*, *b* and get the same answer as in the addition table given earlier. It can be seen from Fig. 2 that the required carry bit is obtained quite simply by performing an *and* operation on bits *a*, *b*. Derivation of the sum bit, however, is a little more complicated. A *not* operation is performed on the carry bit just obtained (the 0 0 0 1 becomes 1 1 1 0) also an *or* operation is performed on the original bits *a*, *b*. An *and* operation is then carried out on these two answers to obtain the correct sum bit.

Examine the sum bits and the carry bits shown in Fig. 2; it will be seen that they are precisely the same as in the addition tables given earlier, viz:—

| $a + b =$ | *sum bit* and | *carry bit* |
|---|---|---|
| $0 + 0 =$ | 0 | 0 |
| $0 + 1 =$ | 1 | 0 |
| $1 + 0 =$ | 1 | 0 |
| $1 + 1 =$ | 0 | 1 |

Up till now only the addition of two bits, or pulses, has been considered. A numerical value, of course, will be represented by a train of pulses. In a serial operation machine—that is where the pulses are transmitted along each wire in sequence—addition is done by performing the above operation on corresponding pairs of bits in the two pulse trains. Consequently, when a carry bit has been generated it must be added to the succeeding pair of bits that will be following a short time-interval behind.

It is not difficult to design a circuit to produce a fixed delay in time so all that would appear to be required is to pass the carry bit through such a circuit and feed it back to the input again. However, this would give three simultaneous inputs to the unit which it cannot accept. The complete adding circuit must, therefore, be a rather more complicated affair. Let the unit so far discussed be called an adding unit and be represented diagrammatically by a single box.

Consider, then, the arrangement shown in Fig. 3. The bits of *b* pass straight through an adding unit called the carry-adding unit and are added to the bits of *a* at the main adding unit until such time as a carry bit is formed. This bit is then delayed and added to the next bit of *b* before this is passed to the main adding unit. Should a carry bit be generated during the carry addition, it in its turn is delayed and added to the following bit of *b*.

It is easy to see that carry bits cannot be generated from both adding units simultaneously to cause confusion at the junction point. At a given time only one of the outputs from the carry-adding unit can be a 1. Consequently, if the carry-adding unit has generated a carry bit, the other output to the main adding unit will be 0. And as the main adding unit can only produce a carry bit when both inputs are 1's the main adding unit can never produce a carry bit at the same time as the carry-adding unit.

By using circuits of the type described it is therefore possible to generate an output pulse train that represents, numerically, the addition of two input pulse trains.

If subtraction is considered in a similar manner, a table can be drawn up corresponding to the addition table

| *a* minus *b* = | *a difference bit* and | *a carry bit* |
|---|---|---|
| 0 – 0 = | 0 | |
| 1 – 0 = | 1 | |
| 0 – 1 = | 1 | –1 |
| 1 – 1 = | 0 | |

Analysis of the above table can obviously be made along similar lines to that for addition.

Multiplication and division in an electronic computer is merely a matter of repetitive additions and subtractions, and these operations can be readily performed by suitable combinations of the simple electronic circuit-elements already described. Fig. 4 shows, for example, three such circuits, each of the *and* type, mounted on a single plug-in chassis as used in the Ferranti Pegasus computer.

The unit in which these computational circuits are assembled is referred to as the arithmetic unit. Although the arithmetic unit forms the computational heart of the computer, the characteristics of the information store and control unit are, of course, equally important.

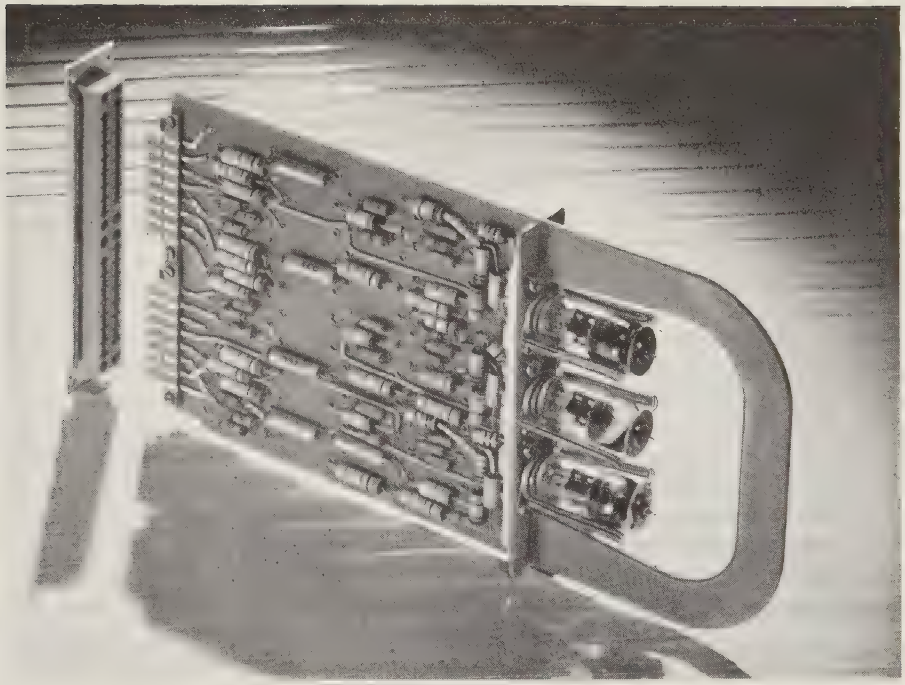


*Fig. 4. Three* 'and' *type circuits mounted on a plug-in chassis as used in the Ferranti Pegasus computer*

Actually, the control unit is constructed from electronic circuit-elements identical to those used in the arithmetic unit.

In computing, reference is often made to a computer making decisions. By this is meant that if, during a calculation, there should be two possible ways of dealing with a number, and the correct course to follow depends upon some attribute of the number, the computer can be programmed to make the appropriate choice. For example, consider the case where invoices are being prepared and a record of the stock position in a stores is being maintained. If a warning is to be given when the stock of a particular item falls below a predetermined danger level, the computer can be programmed to examine the stock total and decide whether it is above or below this level. If below, the machine can be caused to cease printing invoices containing the particular item in short supply and, instead, print a deficiency note on which action must be taken by the store supervisor. This effect is achieved by causing the control, instead of selecting the order next in sequence, to jump to another part of the programme. A study of Fig. 1 may also suggest another idea. If the instructions are in binary coded form, then they will appear to the arithmetic unit as numbers. This being so, if an instruction is sent to the arithmetic unit, subjected to an arithmetical operation, and sent back to the store, it will now appear to the control unit as an entirely different instruction. Evidently, therefore, the machine has the power to change its own instructions, in addition to selecting those it is appropriate to use in a given situation.

It is this ability of an electronic digital computer to take the appropriate course of action in a given situation and also the ability to modify, by itself, the instructions in the programme, that makes these machines such versatile, subtle and powerful data processing tools.

This article has indicated how a computer calculates and the functions of the various units. More powerful computers are being and, of course, will continue to be built, but the greatest need now is for users actually to put these machines to work—in a computing centre or their own business. From the knowledge gained it will then be possible to indicate to the designers the best and most valuable lines along which development should continue, and thus evolve the computers most suitable for commercial data processing work.

# Automatic programming

By A. E. Glennie*

### A SIMPLIFIED TECHNIQUE

Automatic programming offers the hope that—in the not too distant future—the man with the problem will be able to operate an electronic digital computer without having first to learn to use and apply a complicated set of programming rules or call upon the services of a specialist programmer. Surprising though it may appear, a computer can be arranged to recognize instructions written in normal English and convert these into the more detailed instructions needed to operate the machine. Instructions phrased in English given as examples in this article are from automatic codes already in use.

An electronic computer follows a set of instructions provided by the programmer who decides by which steps the computer shall make the required calculation. The versatility of the computer, its ability to process all kinds of data from income-tax calculations to higher mathematics, is due principally to the skill of the programmer in finding how these processes may be stated in the somewhat elementary steps that the machine can execute, and in compiling the list of instructions that will cause the computer to perform the calculation. This list of instructions constitutes the programme. The purpose of automatic programming is to move a large part of the burden of detail programming from the programmer to the computer.

Computers are limited in their application not only by their storage capacity and speed, but also by the difficulties of programming. Many programmes contain thousands, or even tens of thousands, of instructions, and the larger the programme, proportionally the more difficult it is to construct correctly—consequently the greater the time required to put the computer into operation and confirm that it can perform the required calculation.

With automatic programming, the instructions can consist of a collection of natural English phrases instead of the cryptic numerical or alphabetical codes that are now generally used. Adoption will result in shorter programmes and there will be less likelihood of errors being made during the actual writing of the programme.

In addition, automatic programming should enable people to prepare a problem for a computer who would not have either the time or the inclination to learn the detailed, specialized codes in which programmes are now normally written. These people—for example, design engineers and administrators—are interested in the results of computation, not in computers as such. They would be deterred from using the facilities if it meant spending a considerable time learning how to programme the problem or having to explain the problem in detail to a specialist programmer.

Automatic programming also raises the distant hope that one day the programme prepared for any given problem will be the same irrespective of the particular computer chosen to perform the calculation.

Before discussing automatic programming in greater detail something must be said about the methods of programming now in general use. Programmes inside a computer exist as patterns of digits, usually the binary digits 0 and 1. At this level, they may be said to be in machine language. As inferred above, each type of

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*Mr. A. E. Glennie is with the United Kingdom Atomic Energy Authority.

## OF PROGRAMMING FOR ELECTRONIC DIGITAL COMPUTERS

machine has its own machine language which is fixed by the construction of the machine. These languages are not those in which programmes are normally written because human beings find it very difficult to handle the patterns of 0's and 1's that are found in machine languages.

The first step in improving the language from the human being's angle was to devise a code which would enable the instructions to be written in alphabetic letters and decimal numbers—in terms, of course, of the elementary operations of the computer. This programmer's code language is in common use at the present time. The instructions cannot be obeyed directly by the machine, but must first be translated, by the computer, into its own machine language.

A special translation programme has to be prepared for the particular computer but, of course, this programme is permanent unless the programmer's code is altered. It is a short programme because usually there is a very direct relationship between the programmer's code and the machine language; therefore, the translation is often an extremely simple process.

Programmer's codes possess individual characteristics since they incorporate specific ideas of the particular designer of the code. It is, therefore, possible to have many different programmer's codes for the same computer.

### Translation

The idea of automatic programming arose from the realization that computers could be used to translate from one language into another, even where the translations involved were relatively complex. It would therefore be possible to translate from an ideal programmer's language into the machine language, provided that this ideal language could be devised. The ideal language would be one in which programming would be ultra simple and consequently there would be no need to employ a priestly cast of professional programmers. Programming would also be cheaper, quicker and less liable to mistakes.

These ideas appeared quite early in the development of digital computing, and tentative experiments in simple automatic programming were being made as early as 1951. These experiments, however, were hampered by the small information-storage capacity of the machines of those days, as well as by restrictions imposed by the means used to communicate data to the computer.

### Programming codes

Programming codes, like languages, are conditioned by their purpose and the medium on which they are written. For communication with a computer, punched cards or paper tape prepared by a keyboard machine are commonly used. The characters that can be punched are limited to the letters of the alphabet, decimal figures, a few punctuation marks and the simple mathematical signs available on the keyboard. In particular, there is a shortage of mathematical symbols. This limitation is a great disadvantage for scientific work, but probably not serious for business purposes.

Unfortunately, nothing very much can be done to ameliorate the position without building a completely new range of keyboards and printing devices—unless programming notations can be devised to fit within these present restrictions. For example, it is impossible to write many mathematical expressions in the normal manner. A square of some function, such as $x^2$, cannot be written; instead the 17th-century usage must be adopted and the function is portrayed as x * x.

For scientific purposes, there is much drawn from mathematics which has been useful. Mathematical functions such as sine or cosine may be used, subject to the restrictions imposed by the characters available on the keyboards. Examples of such formulae that can be written directly into a programme and automatically translated into the detailed machine language by the computer are:

$$n = x + y + z, \quad \text{or} \quad w = \cos x$$

The translation programmes can provide machine-language orders to perform these simple computations and also arrange for the storage of the variables, x, y and z. Indeed, much more complicated formulae than these can be handled.

The foregoing examples indicate the type of instruction that can be written into an automatic programme, but of course they are of use only for scientific and engineering calculations. Business computations usually involve the processing of large quantities of data and this raises a further problem. It is quite difficult to describe where to find the data to be computed from among a large quantity of associated data.

Consider wage calculations. For each employee there will be several items of data, such as, hours worked, rate of pay, income-tax code number, clock number and surname. An instruction to compute the gross wage of a single employee might be expressed by a simple statement like Wage = Time * Rate. To calculate the gross wages for a group of employees the instruction could be written Wages(N) = time(N) * Rate. Individual clock numbers—indicated by (N) in the equation—would be used to identify the position where the relevant data for a particular employee could be found in the entire file of wages data held.

### Sequence of data

This information, by itself, would still not be sufficient to constitute a programme instruction without, in addition, describing the particular order in which the data concerning the employee is arranged. That is, for instance, where to find the employee's rate of pay among the associated data. Any programming notation must include a means of describing the sequence of the data as it exists, or will exist, on the various storage media—such as punched cards, punched tape or magnetic tape—that the machine handles. Alternatively, it might be possible to establish certain conventions regarding the storage of business data.

Many of the required ideas needed for handling business computations on electronic computers have already been devised, but standard notations for expressing these ideas have not been invented or, rather, have not been generally accepted.

EXAMPLES OF INSTRUCTIONS IN AUTOMATIC CODE AND PROGRAMMER'S CODE

Automatic code:

```
WAGES(N) = TIME(N) * RATE
```

The same instruction in programmer's code (for the IBM 704):

```
LXA  N,4
LDQ  RATE
MPY  TIME,4
STO  WAGES,4
```

By far the larger part of most computer programmes, even in scientific work, deals with making decisions concerning, for example, which particular course of the many available is to be followed in a data handling sequence, or other similar non-numerical operation. The most convenient means of expressing orders of this type is to use English sentences. As an example, consider a decision to be made dependent upon the sign of a quantity X; the following sentence might be used as an instruction:

If X is positive, go to A.

This instruction merely directs the control of the computer to the appropriate part of the programme (A) that defines the computation to be followed when X is positive. It is, of course, just a longer way of expressing something that can be said much more concisely in a programmer's code. Such an instruction might be written in a programmer's code as "TPL A" or "C / / A." But the programme instruction phrased in English has the merit of being much more readable, much easier for the average individual to phrase and conveys the intention to a reader in a way that a succession of symbols in the programmer's code would not.

Other examples of the use of English phrases can be devised for the control of the auxiliary units of a computer, such as printers and input mechanisms. Printing might be done by writing the instruction: Print X (5), this meaning, "Print X to five figures." Many other possible uses of English can be imagined, the aim always being to express matters in the way that will make the programme most intelligible.

Sometimes it is said that automatic programming techniques will enable anybody to programme an electronic computer without the need to study the art of automatic computation. This may be true—indeed, other articles in this issue perhaps infer it—but the real significance of automatic programming is that once the method of attack has been settled, it makes the writing of programmes so much easier.

Maybe it appears surprising that an electronic computer can be programmed to recognize and translate some of the examples of automatic programming notation given in this article. Nevertheless, all the examples quoted are from automatic codes already in use. How then does the computer recognize these mathematical expressions and English sentences? The machine does this by recognizing the rules of construction of English (or mathematical) sentences.

English words are recognized in the translation sequence by the unique signal pattern generated by the individual letters read from the punched tape or punched card. The space or punctuation mark at the end of a word indicates to the machine that the word has ended. A comparison is then made between the signal pattern recorded and stored patterns in order to see whether the word can be recognized. The whole sentence is examined in this way, word by word. The end of a sentence, as stated, is detected by the presence of a punctuation mark or, perhaps, because there is nothing more to read on the card on which the sentence is punched.

### Recognition of significant words

In that earlier sentence, "If X is positive, go to A." the computer may only recognize the words "If," "positive" and "A"—apart, of course, from the numerical expression with which it has to cope. The remainder of the words in the sentence are ignored. The additional words are included in the sentence only to improve the readability and, of course, to make the meaning clear to the user. The presence of "If" shows that the sentence is testing a condition. The word "positive" reveals that the required condition is that "X" is positive. The symbol "A" indicates the part of the programme to use if the condition is satisfied.

Similar methods are employed to analyze mathematical expressions, which are usually distinguished from English sentences by the presence of mathematical signs like +, — and —.

In my experience, notations for automatic codes are constructed by a process of introspection on the part of the inventor, who writes down possible notations and then tries to analyse how he himself recognizes them for what they are and which are the significant words. He seeks to put himself in the position of a teacher teaching a very backward child how to read.

The fact is that the past year has seen the introduction of quite a number of automatic coding systems of varying degrees of sophistication. A typical and rather advanced one for scientific use is IBM's "Fortran," for their Type 704 computer. Many others, for scientific use, are announced, or projected, and a few also for business use as, for example, Remington Rand's Flow-Matic for the Univac computer. To date, scientific systems have been developed more actively than business systems, reflecting the earlier interest of scientists in automatic computation.

### Information storage requirements

It is no accident that the subject has grown into prominence recently, and more so in the U.S.A. than elsewhere. This development is due to the growth in the internal storage capacity of computers. Not only does translation from the automatic programme code into the detailed machine code demand a machine of large internal storage capacity, although not necessarily of great speed, but with a large capacity it is also very much easier to deal with the problem of the arrangement of the data.

In machines with small immediate access store capacity, and where the main storage capacity is provided by magnetic drums, it is quite an art to arrange the storage of programmes so that the computing speed is not seriously reduced by the need to transfer information to and from the drum. Where, however, the high-speed storage is very large, this difficulty is avoided.

The best automatic coding systems produce very efficient programmes for certain types of problem and can produce results quite as good as an experienced programmer using a programmer's code. Usually the penalty on speed and storage is about 10 per cent for machines having a large immediate access store capacity.

Automatic codes have ceased to be research projects and are now in common use in many computer installations in the U.S.A. They have proved popular for certain types of problem where there is much numerical computation to be performed that does not require many decisions to be made. The greatest weakness at the present moment in automatic programmes is perhaps decision making, although this problem will undoubtedly be overcome in time.

# A review of
# ELECTRONIC DIGITAL COMPUTERS
# available in Great Britain

WHERE the volume of commercial data processing work to be performed is sufficiently large to merit the use of a computer, a digital type of machine is chosen. The virtue of digital computing is that, within the capacity of the particular machine, the information that emerges is precise—in contrast with analogue computing, in which the product, although of high accuracy, is approximate. For business and commercial calculations, obviously, precision in handling numbers is a fundamental requirement.

Development of the electronic digital computer has been rapid. Originally, these machines were built principally as mathematical calculating instruments and it is only within the past seven years that special versions have been constructed specifically for commercial data processing work. One of the results of this change in emphasis has been not to alter the nature of the computer itself so much as to increase the variety and scope of the associated units. It is through this equipment that information is presented to the computer, and the results obtained, and the complete computing assembly is commonly referred to as a data processing system.

Any company that contemplates the installation of a digital computer is provided, even in these relatively early days, with an extensive choice. Before a final selection can be made with confidence, a prolonged period of study is necessary on the part of the management concerned. Their own requirements and the capabilities of the various computers must be compared in great and intricate detail in order to establish what is most suitable for their purpose. The choice is made more complex because the obvious attributes of a particular computer are frequently not necessarily the most important. The best system for a particular firm does not necessarily contain the computer with the fastest arithmetic unit, the greatest storage capacity or even the most extensive selection of data input and output units.

One of the imponderables closely connected with the initial choice is in what way the introduction of a computer will alter the structure of management organization. The initial approach in the great majority of cases is to transfer clerical procedures to a computer as they stand. But because the computer is such a powerful and voracious data processing machine, it is almost certain that a management structure built on a foundation of manual information processing must be altered if there is to be the most efficient use of the computer and the full potentialities of the organization are to be realized.

It is quite likely that computer programmes will be devised to control entire aspects of a company—an integrated financial programme may be run, of which payroll and production costs will be only part of the total information produced.

There is no doubt that the advent of the electronic digital computer will slowly, but inexorably change the climate of management and will compel organizations to adapt themselves to the new environment.

The following review gives details of the various manufacturers of electronic digital computers and a brief description of the computers each company builds: the computers that are, or shortly will be, available in Great Britain.

The basic design of individual computers is not expected to change radically within the next few years as a period of consolidation has been reached during which industry and commerce has to learn to use effectively what is already available. Only when this experience has been obtained can it be determined in which direction the computer is best developed for commercial work.

As with all techniques, a jargon arises which is useful in that relatively complex ideas are expressed in concise form. A brief glossary of terms is therefore included at the beginning of the review to amplify the expressions used in the descriptions of the computers.

# A SHORT GLOSSARY OF COMPUTING TERMS

**Acoustic Delay Line.**—Numbers, in the form of coded trains of electrical pulses, that are about to be required for a calculation can be obtained quickly if they are stored in acoustic delay lines. The numbers are continuously transmitted round a short closed circuit that consists of the acoustic delay line and associated electronic units. Although access is required quickly, pulses travel round an electrical circuit so rapidly that it is necessary to slow down the speed at which they circulate. This is done by the acoustic delay line. The electrical pulses are converted into pressure pulses and are transmitted through substances such as quartz, nickel or mercury. The pulses are then reconverted at the other end of the delay line into electrical pulses to continue through the electrical portion of the circuit.

**Address.**—The information stores are subdivided into many individual locations that are identified by code numbers. These locations where data can be stored are referred to as addresses. The particular type of instruction used in a programme is described by the number of addresses quoted in each instruction.

**Alphanumeric.**—Indicates that characters so described may be either alphabetical letters or numerical figures.

**Binary Code.**—Method of expressing numerical values by a numbering system based on 2.

**Bit.**—One binary digit, either 0 or 1.

**Buffer Store.**—Information store, situated between two units of a computing system, that holds data temporarily until the appropriate unit is ready to receive them.

**Fixed Point.**—Numerical values, handled within the computer, where the position occupied by the decimal point within the number is fixed.

**Floating Point.** — Numerical values where the position of the decimal point can be moved, or float, to suit the magnitude of the number. The advantage of floating point over fixed point operation is that with the former there is less likelihood of digits being lost because the length of a number exceeds the capacity of a unit within the computer with the danger that digits at either end could "run off the scale."

**Input Units.**—Provide the means by which data are entered into the computer. These may be punched card readers, punched tape readers, magnetic tape readers or character recognition machines.

**Line Printer.**—Output unit that prints results of computations a line at a time in contrast to a typewriter which prints one character at a time.

**Magnetic Core Store.**—Particular design of information store. Consists of a large number of small magnetic elements arranged in a block.

**Magnetic Drum.** — Rotating drum coated with a magnetic material on which information can be recorded and stored magnetically in a number of separate tracks.

**Magnetic Tape.**—Metallic or plastic tape provided with a magnetic surface on which information can be recorded and stored in a number of separate tracks.

**Mercury Delay Line.** –See acoustic delay line.

**Microsecond.**—Equals 0·000001 second.

**Millisecond.** — Equals 0·001 second.

**Mode of Operation.**—Arithmetical operations are performed on numbers either in parallel or serially. In parallel operation all the corresponding digits of the two numbers used in the calculation are operated on simultaneously. In serial operation the corresponding digits in the two numbers are operated on in sequence, starting with the least significant. Parallel operation is consequently faster than serial operation.

**Nickel Delay Line.**—See acoustic delay line.

**Off-Line.**—Operation of auxiliary equipment, such as a printer, independently of the computer.

**On-Line.**—Operation of auxiliary equipment under the direct control of the computer.

**Plugboard.**—Method of specifying values, or instructions, by permanently wired connections mounted on a board.

**Programme.**—The detailed list of instructions that controls the operation of a computer.

**Regenerative Track.**—Track on a magnetic drum with interconnected reading and writing heads. Information stored on these tracks is continuously read from the drum, transmitted round a closed circuit and recorded back on the drum; consequently, access times to these data are short. Operation is analogous to that of the acoustic delay line.

**Time Sharing.**—Because the arithmetical circuits within a computer can perform calculations so rapidly, it becomes economic to use the arithmetic unit while slower operations, such as the printing of results, are taking place. To do this, two calculations controlled by two separate programmes are entered into the computer. By switching from one programme to the other as the various units within the computer become free to accept work, the maximum use is obtained from all the units within the computer. This is what is termed time sharing.

**Word.**—A number of digits, or bits, assembled into a basic unit of information.

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**The British Tabulating Machine Co., Ltd.**
**17 Park Lane, London, W.1.**
**Number of computer installations in operation in Europe by December, 1958:—36.**

THIS COMPANY is famous for the extensive range of punched card machinery it manufactures under the name Hollerith. It also designs and builds electronic digital computers to complete and augment its range of data processing equipment.

Two electronic digital computers are offered, types 1202 and 1400. Electronic calculators are also constructed. These latter possess many of the operational characteristics of digital computers. There are three types: the 542, 550 and 555. The last of the trio is equipped with a magnetic drum store and can perform the four basic arithmetical calculations—addition, subtraction, multiplication and division. The magnetic drum has a capacity of 1,050 digits stored on five separate tracks.

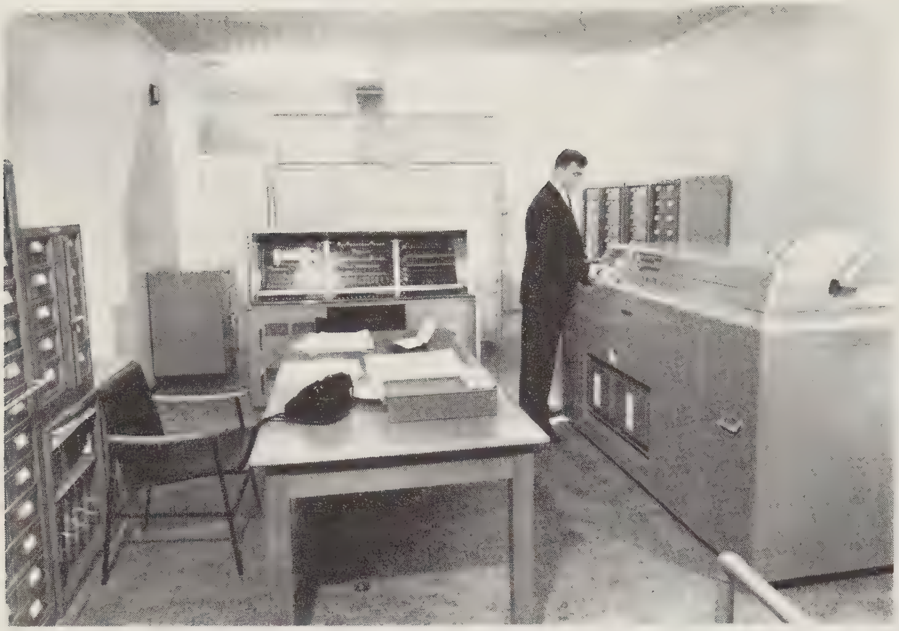


*Fig. 1. This Hollerith type 1201 computer is used by The British Tabulating Machine Co., Ltd., for production control work*

Hollerith electronic computers are used for a wide variety of work, ranging from scientific calculations to those essential business tasks, payroll, stores control and production control. The prototype digital computer was constructed in 1952 and was based on the design of a computer built by Dr. A. Booth, of Birkbeck College.

The first production machine was the type 1200, of which seven were built and installed. This model is no longer produced, neither is the type 1201 which replaced it. Manufacture of the latter machine ceased recently and the current production model is known as the type 1202.

With type 1202, information is read from standard 80-column punched cards at a speed of 85 cards per minute by an input-output tabulator directly connected to the computer. Information is handled within the computer in binary form. Conversion from decimal or sterling input data into binary, and reconversion from binary into the appropriate form of output, is performed automatically.

Two quick access stores each of one word capacity are provided in addition to the magnetic drum store. This latter has a capacity of 4,096 words stored on 256 tracks.

### Hollerith 1202 Computer Characteristics

Numbering system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
    + 2·5 milliseconds (0·0025 second),
    × 20 milliseconds (0·02 second),
    ÷ 50 milliseconds (0·05 second).
Type of instruction—two address.
Word length—40 bits.
Quick access store—valves, of 2 words capacity.
Main store—magnetic drum of 4,096 words capacity.
Data input—punched cards read at 85 cards a minute.
Data output—printed at 85 lines a minute with 100 characters per line.
    —cards punched at 100 a minute.

Units for the first computer to the new type 1400 Hollerith digital computer specification are now being developed. This computer will be able to accept and record information on paper tape, punched cards or magnetic tape. Magnetic drums will provide the main storage capacity. It will be possible to fit up to a maximum of five drums.

Machines built initially will be equipped with a punched card reader and a line printer. Later versions of the machine will be fitted with additional types of input and output equipment as required. Also additional internal storage of 1,000 words will be provided on magnetic cores.

### Hollerith 1400 Computer Characteristics

Numbering system—binary coded decimal.
Time for multiplication—0·85 millisecond (0·00085 second).
Word length—12 digits.
Immediate access store—magnetic core of 100 words capacity.
Main store—magnetic drum of 11,250 words capacity per drum.
Data input (initial machines)—punched cards read at 600 cards a minute.
Data output (initial machines)—printed at 400 lines a minute.

## Burroughs Adding Machine, Ltd.
## 356 Oxford Street, London, W.1.

**Number of installations in operation in Europe by December, 1958:—2.**

Burroughs specialize in the manufacture of a wide range of keyboard machines for book-keeping, accounting and allied clerical work. Many of the later models incorporate electronic units and some make use of documents on which certain basic information is recorded magnetically and read, by means of an electromagnetic reading and writing head, into the machine registers when the document is positioned on the machine carriage.

The parent company is in the United States and the first British factory was established at Nottingham in 1898. After the war Burroughs established additional factories at Strathleven and Cumbernauld in Scotland.

Electronic equipment is manufactured by the Electro-Data Division and Defence Division of the company in the United States. The first computer to be built by Burroughs was the UDEC computer at Wayne, and currently Burroughs are building the 205 and 220 general-purpose computers and the E101 small scientific computer. The 205, 220 and E101 computers are all now commercially available in Europe.

The Burroughs 205 computer may be used for either scientific or commercial work. Quick access storage facilities are obtained by using a regenerative track system on the magnetic drum. External information storage on magnetic tape can be provided. A control unit is also available that enables floating point arithmetical operations to be performed.

### Burroughs 205 Computer Characteristics

Numbering system—binary coded decimal.
Mode of operation of arithmetic unit—serial by digit or parallel by bit.
Times for arithmetical operations:—
+ 1·0 millisecond (0·001 second).
× 9·3 milliseconds (0·0093 second).
÷ 12·7 milliseconds (0·0127 second).
Type of instruction—single address.
Word length—10 digits.
Quick access store—regenerative tracks on magnetic drum of 80 words capacity.
Main store—magnetic drum of 4,080 words capacity.
Data input —keyboard,
—punched tape read at 540 characters a second.
—punched cards read at 240 cards a minute.
Data output—typewriter at 10 characters a second,
—tape punched at 60 characters a second,
—cards punched at 100 cards a minute,
—printed at 150 lines a minute with 120 characters per line.

The Burroughs 220 computer is intended for commercial or scientific work and is equipped with a magnetic core store of 10,000 words capacity. Additional external storage on magnetic tape is available. Automatic floating point calculations can be performed.

### Burroughs 220 Computer Characteristics

Numbering system—binary coded decimal.
Mode of operation of arithmetic unit—serial by digit or parallel by bit.
Times for arithmetical operations:—
+ 0·185 millisecond (0·000185 second),
× 2·070 milliseconds (0·002070 second),
÷ 3·985 milliseconds (0·003985 second).
Type of instruction—single address.
Word length—10 digits.
Immediate access store—magnetic cores of from 2,000 to 10,000 words capacity.
Data input —keyboard,
—punched tape read at 1,000 characters a second.
—punched cards read at 240 cards a minute.
Data output—typewriter at 10 characters a second,
—tape punched at 60 characters a second.
—cards punched at 100 cards a minute,
—printed at 900 lines a minute with 120 characters per line.

The Burroughs E101 digital computer is intended principally for scientific and engineering applications. The computer is about the size of an office desk, and one of the important aims at the time it was designed was to produce a computer of low capital cost.

Programme instructions are given by inserting pins in a plugboard panel. Up to 128 separate instructions can be programmed in this way and, when required, the operator can override the automatic programme manually.

Data are entered manually by a keyboard of accounting-machine pattern, although a punched paper tape or punched card reading unit, may be fitted if desired. A magnetic drum store is provided.

### Burroughs E101 Computer Characteristics

Numbering system—pulse coded decimal.
Operation of arithmetic unit—serial.
Typical times for arithmetical operations:—
+ 50 milliseconds (0·05 second),
× and ÷ 250 milliseconds (0·25 second).
Type of instruction—single address.
Word length—12 decimal digits.
Main store—magnetic drum of 220 words capacity.
Data input —keyboard,
—punched tape at 20 characters a second,
—punched cards at 15 cards a minute.
Data output—tape punched at 20 characters a second,
—printed at 108 words a minute.
Number of installations in Europe by December, 1958:—2.

## Elliott Brothers (London), Ltd.
**Century Works, Lewisham, London, S.E.13.**

## The National Cash Register Co., Ltd.
**206 Marylebone Road, London, N.W.1.**

**Number of computer installations in operation in Europe by December, 1958:—24.**

Elliott Brothers (London), Ltd., are one unit in a large group of companies, Elliott-Automation, Ltd., who build comprehensive automatic control systems. Elliott Brothers are the company within this group that specializes in, among other things, the design and construction of electronic digital computers. Associated with Elliott Brothers in the development of electronic digital computers for commercial data processing work, but outside the Elliott-Automation Group, is The National Cash Register Co., Ltd., which is responsible for all sales of commercial machines.

Elliott Brothers, alone, are at present concerned with the design, development and sale of electronic digital computers for scientific work and other specialized applications. The 402 computer and its variants come into this classification. Earlier types such as the 401 are no longer manufactured, and specialized models such as the 403 and 404 are never likely to be produced in quantity.

Two computers are marketed by The National Cash Register Co., Ltd., under the name National-Elliott; these are the 405 and the 802. The 405 is referred to as a data processing system and includes the large number of auxiliary units that are normally required for commercial work. A new version of this data processing system has been announced recently—the 405m.

The agreement between the two companies to co-operate on commercial installations came into being in June, 1956, and the first system was supplied to Norwich City Council.

The National-Elliott 802 general-purpose computer is a small desk-size machine. Provision has been made, during the design, to enable the computer to be connected directly to special input and output recording mechanisms. A composite system known as the 609, which incorporates the National-Elliott 802, has been designed specifically for use in industrial process control work.

The Elliott 402 computer was designed for scientific engineering and statistical work. The two versions of this computer being manufactured, at present, are the types 402 E and 402 F.

When additional storage capacity is needed, a magnetic film storage system can be fitted. This was specially developed by Elliott Brothers and consists of 35mm photographic film-base material coated with ferrous oxide. The magnetic film is used in exactly the same manner as magnetic tape, except that mechanical indexing is possible since the film is transported mechanically by teeth which engage with the sprocket holes in the film.

The 402 E performs fixed point arithmetical calculations, while the 402 F, which is basically of similar design, can perform both fixed or floating point calculations.

**Elliott 402 E and F Computer Characteristics**

Number system—binary.
Mode of operation of arithmetical unit—serial.
Average times for arithmetical operations:—
  + 0·2 millisecond (0·0002 second),
  × or ÷ 3·3 milliseconds (0·0033 second).
Type of instruction—single address.
Word length—32 bits.
Quick access store—nickel delay lines of 17 words capacity.
Main store—magnetic drum of 4,992 words capacity.
Optional auxiliary storage—35mm magnetic film.
Data input —punched tape read at 180 characters a second,
  —punched cards read at 400 cards a minute.
Data output—tape punched at 33 characters a second.

Number of installations in operation in Europe by December, 1958:—10.

The National-Elliott 405 data processing system consists of a number of interconnected units, and various types of auxiliary equipment are chosen to suit the specific application. The system centre is a complete computer in itself and consists of three cabinets which contain the control, arithmetic units and an immediate access store.

For the main information store either a magnetic drum of 4,992 words capacity or a magnetic disc of 16,384 words capacity is fitted. Magnetic film units can also be associated with the system. About 300,000 words can be retained on each 1,000 ft reel of 35mm film and as many as 64 magnetic film storage units can be connected in one system.

**National-Elliott 405 Data Processing System Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
  + 0·102 millisecond (0·000102 second),
  × or ÷ 3·264 milliseconds (0·003264 second).
Type of instruction—single address.
Word length—32 bits.
Quick access store—nickel delay lines of 512 words capacity.
Main store—magnetic drum of 4,992 words capacity or magnetic disc of 16,384 words capacity. Double capacity, 32,768 words, can be provided if required.
Data input —punched tape read at 180 characters a second,
  —punched cards read at 400 cards a minute,
Data output—tape punched at 33 characters a second,
  —cards punched at 120 cards a minute,
  —magnetic tape recorded at 350 characters a second,
  —printed at up to 300 lines a minute.
Number of installations in operation in Europe by December, 1958:—14.

The National-Elliott 405 m data processing system is essentially the same as the 405 system. However, a magnetic core immediate access store of 1,024 words capacity is provided; a new paper tape reader operating at 1,000 characters a second can be supplied, also a high-speed tape unit that can punch 300 characters a second. A faster line printer is also available operating at 600 lines a minute.

Physically, the National-Elliott 802 computer is a small machine—as stated earlier, it is of desk size—and, in its construction, extensive use is made of transistors. All information is retained in a magnetic core store, and input and output data are recorded on punched paper tape. It is said that a specialist programming staff is not required, because, with a short instructional course, the user can learn to programme the computer himself.

**National-Elliott 802 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
  + 0·612 millisecond (0·000612 second),
  × or ÷ 21·4 milliseconds (0·0214 second).
Type of instruction—single address.
Word length—33 bits.
Immediate access store—magnetic core of 1,020 words capacity.
Data input —punched tape at 170 characters a second.
Data output—tape punched at 25 characters a second.

**E.M.I. Electronics, Ltd.**
**Hayes, Middlesex.**

Although E.M.I. started design and development work on electronic digital computers later than the majority of other manufacturers, their initial machine, the Emidec 1100, is claimed to be the first computer commercially available to make extensive use of magnetic cores and transistors as circuit elements. This computer has been designed primarily for commercial and industrial data processing work. The first Emidec 1100 computer is scheduled to be completed in January of this year.

In addition, the company has obtained a contract from the National Research Development Corporation to develop a high-speed computer. This computer, known as the Emidec 2400, will be completed during this year; it makes extensive use of magnetic tape.

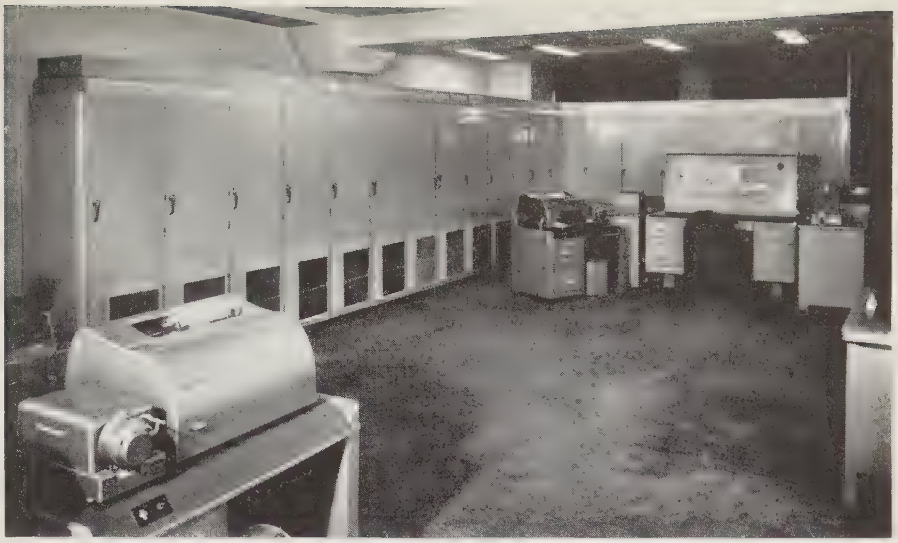


*Fig. 2. A National-Elliott* 405 *business data processing computer installation. A new model of this computer has recently been announced, the National-Elliott* 405*m*

A variety of input and output equipment can be used in conjunction with the Emidec 1100. Information can be presented on punched cards, punched tape or magnetic tape. Similarly, results can be recorded on punched cards, punched tape, magnetic tape or they can be printed directly by a line printer.

The immediate access store consists of magnetic cores. A magnetic drum provides the main internal store. When required, high-speed magnetic tape units for additional storage can be connected.

Automatic conversion is provided to change data in decimal or sterling values into the binary code used by the computer. Automatic translations from binary into decimal, or sterling, can also be performed before the results are delivered to the output unit.

**Emidec 1100 Computer Characteristics**

Numbering system—binary.
Mode of operation of arithmetic unit—parallel.
Typical times for arithmetical operations
    + 0·125 millisecond (0·000125 second).
    × and ÷ 1·12 milliseconds (0·00112 second).
Type of instruction—two address.
Word length—36 bits.
Immediate access store—magnetic cores of 1,024 words capacity.
Main store—magnetic drum of 8,192 or 16,384 words capacity.
Data input —punched cards read at 400 cards a minute.
    —magnetic tape read at 20,000 characters a second.
    —punched tape read at 300 characters a second.
Data output—cards punched at 100 cards a minute.
    —magnetic tape recorded at 20,000 characters a second.
    —tape punched at 25 characters a second.
First machine to be completed by January, 1959.

The Emidec 2400 Computer is designed as a fast general-purpose machine suitable for business and commercial work as well as scientific and engineering computations. All the auxiliary equipment can be controlled either by the programme or from the control desk.

Time sharing is possible, and this allows up to four input or output units to be operating at the same time as computations are being performed. Magnetic cores are used for quick access storage, and data in bulk are stored on magnetic tape four inches in width from which characters can be read at 20,000 per second.

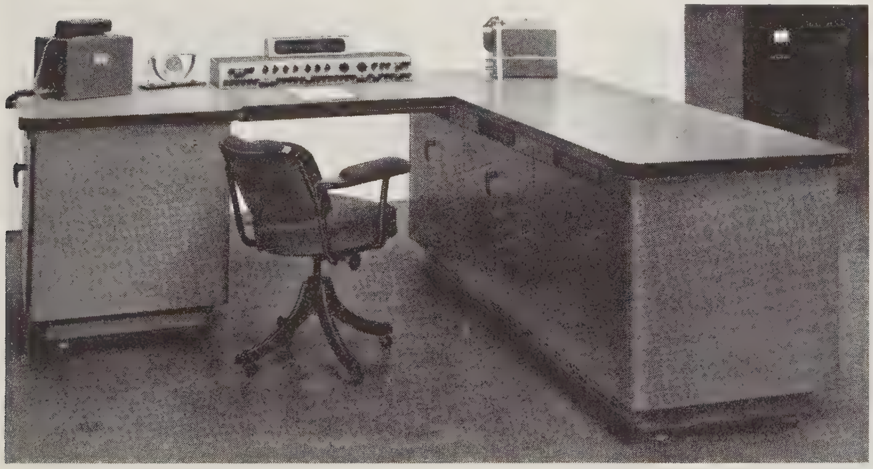


*Fig. 3. Transistors are used extensively in the construction of the National-Elliott* 802 *digital computer*

**Emidec 2400 Computer Characteristics**

Numbering system—binary.
Mode of operation of arithmetic unit—parallel.
Times for arithmetical operations:—
+ 0·026 millisecond (0·000026 second),
× 0·11 millisecond (0·00011 second).
Type of instruction—two address.
Word length—36 bits or six alphanumeric characters.
Immediate access store—diode capacitor of 64 words capacity, plus magnetic core store of 4,096 words capacity.
Main storage—magnetic tape 1in in width and 4in in width.
Data input —keyboard recording on to magnetic tape: up to 112 units may be connected,
—tape read at 300 characters a second,
—punched cards read at 300 cards a minute,
—magnetic tape read at 20,000 characters a second.
Data output—by punched tape units, punched card units and line printers,
—magnetic tape recorded at 20,000 characters a second.

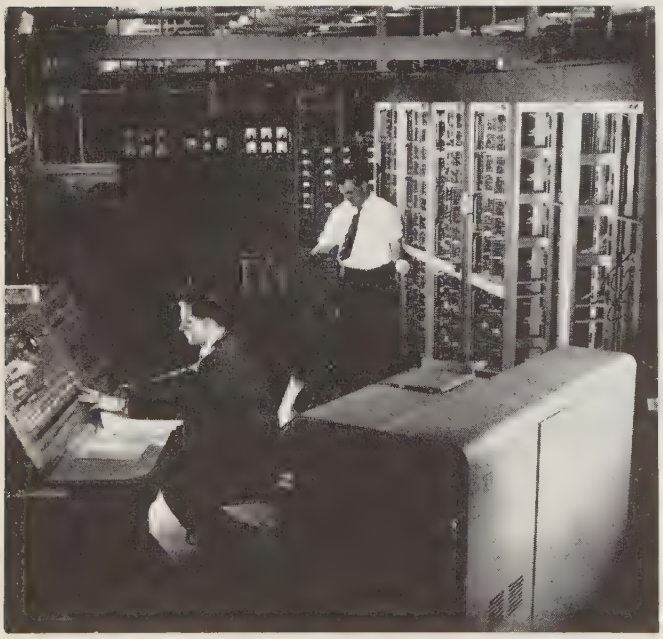
**The English Electric Co., Ltd.**
**Marconi House, Strand, London, W.C.2.**

**Number of computer installations in operation in Europe by December, 1958:—22.**

English Electric manufacture one type of electronic digital computer—the Deuce. This machine was developed from a computer built at the National Physical Laboratory known as the Pilot-model Ace, which was completed early in 1952. The first Deuce was built in 1955 and was installed at the Nelson Research Laboratories of the company at Stafford. Since then, a number of Deuce computers have been built and delivered. All these computers are engaged on scientific and industrial design problems. The Deuce, however, may be used for commercial data processing in association with suitable auxiliary equipment, though no such installation is in operation at present.

Various items of auxiliary equipment are being designed by English Electric to extend the range of documents on which data can be presented to the computer, or obtained from it, although the policy is to use existing equipment where appropriate. One auxiliary unit developed is a high-speed punched tape reader operating at 850 characters a second, and another unit recently made available is a card programmed typewriter that will print ten characters a second.

*Fig. 4. Testing the main assembly of an English Electric Deuce Mark II electronic digital computer*



Deuce was originally designed to read and record data on punched cards. The design has now been modified, and punched tape input and output equipment can be operated in conjunction with the Deuce Mark II. For commercial data processing work it is also proposed that the existing storage capacity shall be augmented by magnetic tape units. Initially, a magnetic tape unit imported from the U.S.A. was fitted on a development machine, but later systems will be provided with British magnetic tape units designed and built by Decca.

**English Electric Deuce Mk. II Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
+ 0·064 millisecond (0·000064 second).
× or ÷ 2 milliseconds (0·002 second).
Word length—32 bits.
Type of instruction—two address.
Quick access store—mercury delay lines of 402 words capacity.
Main store—magnetic drum of 8,192 words or 16,384 words capacity.
Data input —punched cards read at 200 cards a minute,
—punched tape read at 850 characters a second.
Data output—cards punched at 100 cards a minute,
—tape punched at 30 characters a second.

**Ferranti, Ltd.**
**Hollinwood, Lancashire.**

**Number of computer installations in operation in Europe by December, 1958:—30.**

Ferranti began to design electronic digital computers in November, 1948, in conjunction with Manchester University who had already developed items of computing equipment. The first computer built by Ferranti, known as the Mark 1, was installed at Manchester University and officially started operating on July 28th, 1951. This computer was the first to be manufactured in this country by an industrial organization and the first electronic computer in the world to be marketed commercially. Several other computing devices and special-purpose computers were built by Ferranti about this time, including Nimrod—shown at the Festival of Britain. Also, a further Mark 1 computer was installed at the University of Toronto in 1952.

A modified version of the Mark 1 computer was then produced, known as the Mark 1*, and altogether seven of these machines were constructed, the first being installed in 1953. Two of these computers were exported—one to Amsterdam and the other to Rome.

In November, 1953, the design of a new computer was started. This work was sponsored by the National Research Development Corporation and the computer developed is now known as Pegasus. At the same time Manchester University, again in association with Ferranti, were constructing a large high-speed computer for

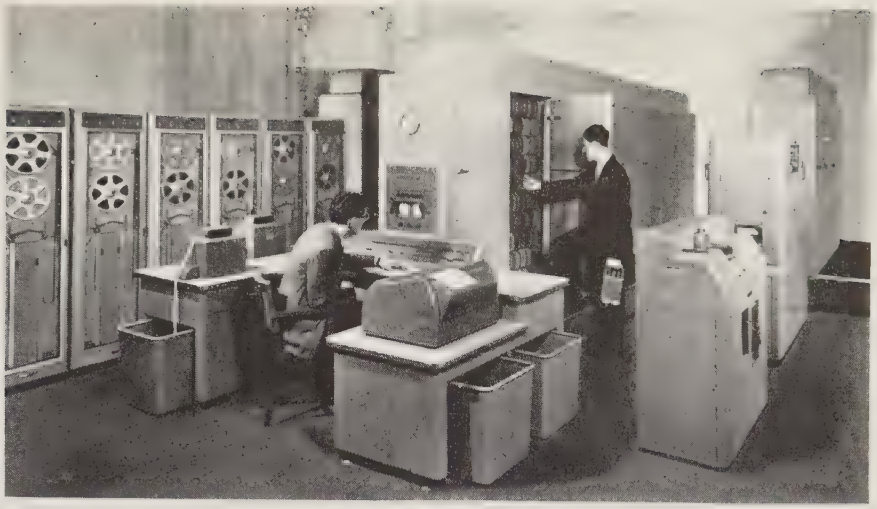


*Fig. 5. The Ferranti Perseus data processing system was specially designed for commercial work and the main storage capacity is provided on magnetic tape*

scientific and technical calculations; this computer was christened Mercury.

As a result of programme studies made on the Mark 1 computer at Manchester, and the interest shown in the use of digital computers for commercial work, in contrast with scientific work, the manufacture of a computer specifically intended for commercial data processing was started in 1955. The first of these machines—Perseus—is now completed and is to be exported to Sweden early this year, closely followed by a second to South Africa.

Ferranti now manufacture three computers: Pegasus, Mercury and Perseus. The earlier Mark 1 machines are no longer produced. One Pegasus computer is built each month, Mercury production is six per year, and Perseus production is at the rate of two per year.

The Pegasus 2 is a medium-size multi-purpose computer. This new version of the Pegasus has been designed to serve as the centre of a data processing system. Two systems of this type have been installed and are in regular use. Three kinds of system can be built that may be equipped with magnetic tape units to provide large capacity storage facilities. One system is known as the converter data processing system. Data recorded on punched cards are transcribed on to magnetic tape by a special converter unit. The magnetic tape is then used for entering the information into the computer. Results are recorded on magnetic tape, and transcription of the data on to punched cards can also be performed by the same converter unit.

The second version is known as the direct system, since data recorded on punched cards can be entered directly into the computer and the results obtained are also punched into cards. This computer may be integrated with existing Hollerith, IBM and Powers-Samas punch card equipment.

A third "common language" data processing system uses punched paper tape for input and output data. Paper tapes produced by cash registers, typewriters, and accounting machines fitted with tape punching units, can consequently be fed directly into the computer.

**Ferranti Pegasus 2 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
+ 0·3 millisecond (0·0003 second),
2 milliseconds (0·002 second),
÷ 5·5 milliseconds (0·0055 second).
Type of instruction—single address.
Word length—39 bits.
Quick access store—nickel delay lines of 55 words capacity.
Main store—magnetic drum of 9,216 words capacity.
Data input —punched tape read at 300 characters a second,
—punched cards read at 200 cards a minute,
—magnetic tape read at 9,250 characters a second.
Data output—tape punched at 240 characters a second,
—cards punched at 100 cards a minute,
—magnetic tape recorded at 9,250 characters a second,
printed off-line at 150 lines a minute with 92 characters per line.

Pegasus installations in operation in Europe by December, 1958:—22.

The Ferranti Mercury is a large high-speed digital computer intended primarily for scientific and technical calculations. Numbers are handled within the computer in floating point binary form. Magnetic tape units, up to eight in number, may be fitted if required. Magnetic drums provide the main storage capacity.

**Ferranti Mercury Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Times for arithmetical operations:—
+ 0·18 millisecond (0·00018 second),
× 0·3 millisecond (0·0003 second),
÷ 3·5 milliseconds (0·0035 second).
Type of instruction—single address.
Word length—40 bits.
Immediate access store—magnetic cores of 1,024 words capacity.
Main store—magnetic drum of 32,768 words capacity (maximum for 4 drums).
Data input —punched tape read at 300 characters a second,
—punched cards read at 200 cards a minute,
—magnetic tape read at 9,250 characters a second.
Data output—tape punched at 240 characters a second,
—cards punched at 100 cards a minute,
—magnetic tape recorded at 9,250 characters a second.

Number of installations in operation in Europe by December, 1958:—8.

The Ferranti Perseus computer was designed specially for commercial work. Its important features are that there is a direct relationship between the letters and numbers as they appear in print and as they are portrayed within the computer. It can perform arithmetic directly with sterling or decimal data, or with data expressed in other scales of measurement—inches, feet, yards, and so on.

Nickel delay lines are used for the quick access stores, and magnetic tape provides the main storage capacity. Magnetic drum storage can be fitted if needed.

### Ferranti Perseus Computer Characteristics

Number system—binary coded.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
  + 0·234 millisecond (0·000234 second),
  0·78 millisecond (0·00078 second),
  ÷ 11·0 milliseconds (0·011 second).
Type of instruction—single address.
Word length—72 bits comprising 12 alphabetical or numerical characters.
Quick access store—nickel delay lines of 1,024 words capacity.
Main store—magnetic tape of 3,200,000 words capacity (16 tape units).
Data input —punched cards read at 300 cards a minute,
  —magnetic tape read at 2,880 characters a second.
Data output—magnetic tape recorded at 2,880 characters a second.
  —off-line printing at 300 lines a minute.

### IBM United Kingdom, Ltd.
### 101 Wigmore Street, London, W.1.

**Number of computer installations in operation in Europe by December, 1958:—over 77.**

The British company, IBM United Kingdom, Ltd., was established in 1951 and operates in close association with the IBM World Trade Corporation. IBM ancestry can be traced back to the earliest days of punched card machinery—the days when Dr. Herman Hollerith conceived the idea of recording and processing information by means of holes punched in cards. The name International Business Machines was adopted in 1924.

IBM United Kingdom, Ltd., has its main factory at Greenock, Scotland, where the IBM 650 computer is produced, as well as conventional punched card equipment and electric typewriters.

The IBM 650 was one of the earliest computers to go into full-scale production, and it is stated that over 1,200 have been installed throughout the world. A range of more powerful computers—the 700 series—is also in production in the United States and France. The principal feature of the 700 series is the provision of a large capacity immediate access store using magnetic cores, augmented by magnetic drum and magnetic tape storage units. One IBM 704 has been installed in Britain at the Atomic Weapons Research Establishment, where it is used solely for scientific calculations.

IBM also manufacture an electronic calculating machine, the IBM 628, which possesses many of the attributes of a digital computer. This calculator is equipped with a magnetic core information store of 320 digits capacity.

The title IBM 305 Ramac denotes "random access memory accounting" machine. This machine was specially designed for commercial data processing work, and the large random access memory is the feature which distinguishes it from other computers.

Information is recorded on metal discs. Each disc is 2 ft in diameter, and one information storage unit contains 50 of these discs. The discs are located one above the other on a common axis and rotate at 1,200 r.p.m. Arms fitted with reading and writing heads are used to obtain or record information. These arms can be moved quickly to the required track on the appropriate disc and consequently there is rapid access to the 5 million or 10 million alphabetical or numerical characters stored. As many as four IBM 381 remote printing stations may also be connected to the system. These stations provide a typed output at distances up to 2,500 feet from the system console.

### IBM 305 Ramac Characteristics

Number system—binary coded decimal.
Mode of operation of arithmetic unit—serial.
Times for arithmetical operations:—
  + 30 milliseconds (0·03 second),
  130 milliseconds (0·13 second),
  ÷ 220 milliseconds (0·22 second).
Type of instruction—two address.
Word length—variable.
Immediate access store—magnetic cores of 100 digits capacity.
Main store—magnetic drum of 2,400 characters capacity.
Backing store—magnetic disc of 5 million or 10 million alphabetical or numerical characters capacity.
Data input —punched tape read at 20 characters a second,
  —punched cards read at 125 cards a minute.
Data output—cards punched at 100 a minute,
  —printed at 2,400 characters a minute.
Installations in current operation in Europe by December, 1958:—2.

The IBM 610 automatic decimal point computer is a small machine into which information is entered directly—by plugboard, by keyboard or by punched tape—and computation proceeds concurrently with the entry of the data and the programme. The computer is referred to as an automatic decimal point computer. This relates to the facility whereby the operator inserts the decimal point as part of the data and, after each operation, this point is automatically positioned in the arithmetic unit. The computer is chiefly used to assist engineers with design calculations, and can be operated with either decimal or octal numbering systems.

### IBM 610 Computer Characteristics

Number system—decimal or octal.
Mode of operation of arithmetic unit—serial (word) or parallel (digit).
Average times for arithmetical operations:—
  + 0·28 second,
  fixed point 1·15 seconds, automatic 1·36 seconds.
  ÷ fixed point 1·15 seconds, automatic 1·43 seconds.
Type of instruction—two address.
Word length—15 digits.
Store—magnetic drum of 2604 digits capacity.
Data input —keyboard,
  —punched tape at 12 characters a second.

Data output—tape punched at 12 characters a second,
—electric typewriter at 12 characters a second.

Perhaps the most famous of the IBM computers is the IBM 650. It was first marketed in 1953 and, since then, auxiliary equipment has been added to extend its capabilities, especially as a commercial data processing tool. The main storage of the machine is provided by a magnetic drum.

Various items of basically standard punched card equipment can be connected directly to the computer as required. These include punched card input-output units, and high-speed line printers. Also up to six magnetic tape units may be connected.

The information storage capacity of the computer system may be varied by the addition of special storage units. The 635 unit has an immediate access magnetic core storage of 60 words capacity and an automatic floating decimal device.

Another storage unit that can be operated alone or in conjunction with the computer is the IBM 355 Ramac store. Up to four of these units can be used in a data processing system, and each unit has a capacity of 6 million decimal digits. These stores operate in a manner similar to those described in the IBM 305 Ramac machine.

**IBM 650 Computer Characteristics**

Number system—binary coded decimal.
Mode of operation of arithmetic unit—serial by digit; parallel by bit.
Times for arithmetical operations:—
+ 0·8 to 3·1 milliseconds (0·0008 to 0·0031 second),
× 2·6 to 19·6 milliseconds (0·0026 to 0·0196 second),
÷ 5·0 to 25·3 milliseconds (0·005 to 0·0253 second).
Type of instruction—two address.
Word length—10 decimal digits.
Immediate access store—magnetic cores of 60 words capacity.
Main store—magnetic drum of 2,000 words capacity.
Data input —punched cards read at 200 cards a minute,
—magnetic tape read at 15,000 characters a second.
Data output—cards punched at 100 cards a minute,
—magnetic tape recorded at 15,000 characters a second,
—printed at 150 lines a minute with 120 characters a line.
Installations in current operation in Europe by December, 1958:—over 70.

The IBM 704 computer was built principally for scientific and design calculations. Over 200 of these computers have been ordered, and approximately 100 have been installed. Either fixed point or floating point arithmetical calculations can be performed.

**IBM 704 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—parallel.
Average times for arithmetical operations:—
+ fixed point 0·024 millisecond (0·000024 second),
floating point 0·084 millisecond (0·000084 second).
× and ÷ fixed point 0·138 millisecond (0·000138 second),
and ÷ floating point 0·144 millisecond (0·000144 second).
Type of instruction—single address.
Word length—36 bits.
Immediate access store—magnetic cores of from 4,096 to 32,768 words capacity.
Main store—magnetic drum of 8,192 or 16,384 words capacity.
Data input —punched cards read at 250 cards a minute,
—magnetic tape read at 15,000 characters a second.
Data output—cards punched at 100 cards a minute,
—off-line printing at 500 or 1,000 lines a minute,
—magnetic tape at 15,000 characters a second.
Installations in current operation in Europe by December, 1958:—3.

In the IBM 705 computer, which is intended primarily for commercial data processing, information is handled throughout in coded numerical or alphabetical form. The system consists of a central computer linked to a number of associated units, and the transmission of data within the system is via magnetic tape.

**IBM 705 Computer (Models 1, 2, 3) Characteristics**

Number system—binary coded decimal.
Mode of operation of arithmetic unit—serial by digit; parallel by bit.
Times for arithmetical operations:—
+ 0·204 millisecond (0·000204 second), Models 1 and 2);
0·116 millisecond (0·000116 second), Model 3.
× 0·800 millisecond (0·0008 second), Models 1 and 2;
0·600 millisecond (0·0006 second), Model 3.
÷ 1·8 milliseconds (0·0018 second), Models 1 and 2;
1·4 milliseconds (0·0014 second), Model 3.
Type of instruction—single address.
Word length—variable.
Immediate access store—magnetic cores of 40,000 or 80,000 characters capacity.
Backing store—magnetic drum of 60,000 characters per drum capacity; up to 30 drums may be fitted.
Data input —punched cards read at 150 cards a minute,
—magnetic tape read at 15,000 characters a second.
Data output—cards punched at 100 cards a minute,
—magnetic tape recorded at 15,000 characters a second,
—console typewriter at 10 characters a second.

Installations in current operation in Europe by December, 1958:—2.

The IBM 709 computer is a large capacity digital machine, developed from the IBM 704 and used for both scientific and commercial work. Either floating point or fixed point arithmetical calculations may be performed. The magnetic tape units used with this machine are similar to those for the IBM 650, 704 and 705 systems.

**IBM 709 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—parallel.

Times for arithmetical operations:

+ fixed point 0·024 millisecond (0·000024 second).
floating point 0·084 millisecond (0·000084 second).
fixed point 0·036 to 0·24 millisecond (0·000036 to 0·00024 second).
floating point 0·084 to 0·204 millisecond (0·000084 to 0·000204 second).
fixed point 0·24 millisecond (0·00024 second),
floating point 0·216 millisecond (0·000216 second).

Type of instruction—single address.
Word length—36 bits.
Immediate access store—magnetic cores of from 4,096 to 32,768 words capacity.
Main store—magnetic drum of 8,192 or 16,384 words capacity.
Data input and output—as for IBM 704.

Most recent of the IBM computers to be announced is the IBM 7070. This is equipped with transistors throughout, and is designed on the "building block" principle; thus additional units can be fitted to the system as required. Input-output units and other items of auxiliary equipment have been specially designed for use with the computer.

Information is retained in magnetic core stores, or on a maximum of four Ramac-type disc storage units. Magnetic tape can be used to provide large capacity storage where required. Delivery times for Europe are estimated to be two years.

### IBM 7070 Computer Characteristics

Number system—binary coded decimal.
Mode of operation of arithmetic unit—parallel by bit; serial by digit.
Times for arithmetical operations:—

+ 0·072 millisecond (0·000072 second).
1·16 milliseconds (0·00116 second).
3·756 milliseconds (0·003756 second).

Type of instruction—single address.
Word length—10 digits.
Immediate access store—magnetic cores of 50,000 or 100,000 digits capacity.
Backing store—magnetic disc of 6 million digits capacity per storage unit; up to four units may be fitted.
Data input —punched cards read at 400 cards a minute.
—magnetic tape read at 62,500 characters a second.
Data output—cards punched at 250 cards a minute.
—magnetic tape recorded at 62,500 characters a second.
—printed at 150 lines a second with 120 characters a line.

### Leo Computers, Ltd.
### Elms House, Brook Green, London, W.6.

**Number of computer installations in operation in Europe by December, 1958:—5.**

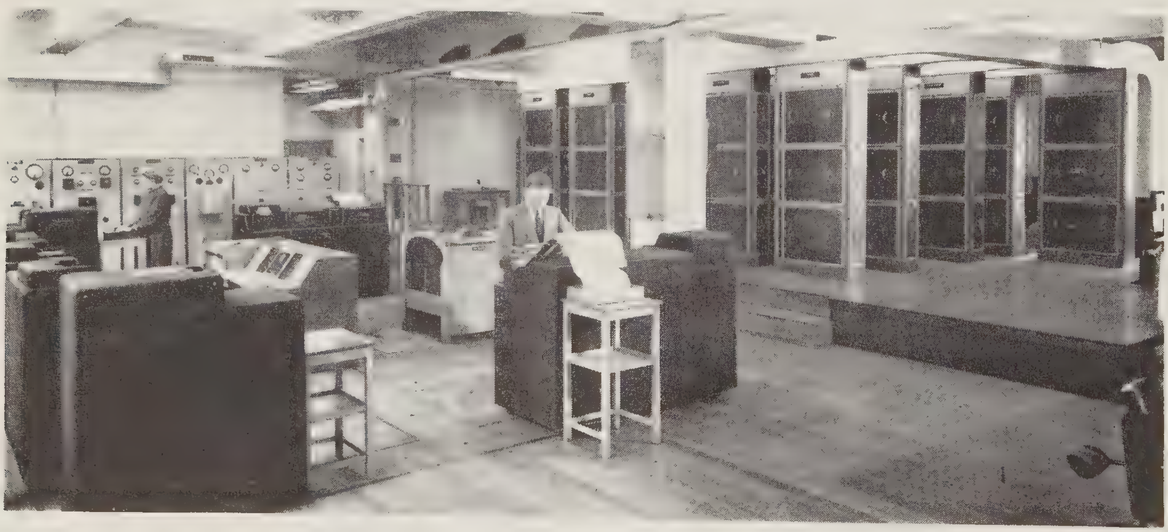
LEO WAS THE first electronic digital computer in Great Britain specifically designed for commercial data processing work. LEO I, the original machine, has been engaged on clerical work regularly since 1953 and, more recently, has operated on a 24-hour basis for seven days per week.

LEO I incorporates many of the design features of the EDSAC computer (Electronic Delayed Storage Automatic Computer) at Cambridge. While EDSAC in itself was not suitable for commercial work, J. Lyons & Co., Ltd., took a close interest in its development. A design team was formed in 1949 to develop a computer for commercial applications and this work resulted in the construction of LEO I.

As a result of the experience gained on LEO I, both from the constructional and operational aspects, the basic design was developed and LEO II produced. The first LEO II started work in June, 1957. It was installed at Elms House, which is adjacent to Cadby Hall, the home of the original LEO I.

LEO II is more flexible in operation, is three times faster, and a greater variety of storage and input and output units can be used in conjunction with it. These include magnetic drums of the Ferranti Mercury type, magnetic tape units built by Decca, Powers-Samas

*Fig. 6. LEO I has been employed on commercial data processing work since* 1953



Samastronic high-speed line printers and Hollerith card readers and card punches.

On a service basis LEO I and LEO II are calculating the weekly pay of 40,000 people and performing various other tasks, such as invoicing, sales statistics, assembling warehouse orders and stock control. Applications in the fields of market research and insurance and of a scientific nature are also performed on these installations.

LEO II, although expressly designed for large-scale commercial data processing, does include the necessary facilities for complex mathematical work. Provision is made for automatic conversion and reconversion between binary, decimal and sterling values.

**LEO II Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Times for arithmetical operations:—
+ 0·34 millisecond to 0·66 millisecond (0·00034 to 0·00066 second),
× 0·66 to 3·5 milliseconds (0·00066 to 0·0035 second),
÷ 3·5 milliseconds (0·0035 second).
Type of instruction—single address.
Word length—19 or 39 bits.
Quick access store—mercury delay lines of 2,084 words (19 bits each) capacity, plus 14 words (38 bits each) immediate access store capacity.
Auxiliary store—magnetic drum of up to 65,536 words capacity on 4 drums,
—magnetic tape; reading and writing speed on tape at 10,000 digits per second.
Data input —punched cards read at 200 cards a minute,
—punched tape read at 200 characters a second.
Data output—cards punched at 100 cards a minute,
—printed at 300 lines a minute with 140 characters per line.

**Metropolitan-Vickers Electrical Co., Ltd.**
**Trafford Park, Manchester, 17.**

**Number of computer installations in operation in Europe by December, 1958:—2.**

METROPOLITAN-VICKERS started work on the design of electronic digital computers in November, 1954. Initially, the aim was to produce a mathematical computer using transistors. The first of these computers, known as the Metrovick 950, was installed at Trafford Park in 1956.

Because the available input and output speeds are not suitable for commercial work, a new computing system is now being developed known as the Metrovick 1010 data processing system. It is proposed that a variety of input and output units should be operated by the computer, including punched card and punched tape units and high-speed line printers.

The Metrovick 950 has been used for solving a wide range of mathematical, scientific and engineering problems. Information is stored on a magnetic drum, and one track on the drum is used as a quick access store. The information on this particular track is regenerated by interconnected reading and writing heads.

**Metrovick 950 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
+ 3 milliseconds (0·003 second),
× 8 milliseconds (0·008 second),
÷ by programming (0·75 second).
Type of instruction—two address.
Word length—32 bits.
Quick access store—regenerative track on magnetic drum of 8 words capacity.
Main store—magnetic drum of 4,096 words capacity.
Data input —punched tape read at 250 characters a second.
Data output—tape punched at 25 characters a second,
—teletypewriter at 7 characters a second.

The Metrovick 1010 computer is designed as a commercial data processing system. Either fixed point or floating point calculations can be performed. Transistors and printed circuits are used throughout the construction.

Decca twin magnetic tape units of 320,000 words capacity per reel will be fitted where considerable quantities of information need to be stored. A magnetic drum is provided for the main store and a large low-speed magnetic drum for a high-capacity random access store.

Time shared operations are possible and any two programmes can be performed concurrently.

**Metrovick 1010 Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—parallel.
Average times for arithmetical operations:—
+ 0·020 millisecond (0·00002 second),
× or ÷ 0·150 millisecond (0·00015 second).
Type of instruction—single address.
Word length—long 44 bits, short 13 bits.
Immediate access store—magnetic cores of 2,048 or 4,096 long words capacity.
Main store—magnetic drum of 8,192 long words capacity.
Random access store—magnetic drum of 60,000 long words capacity.
Data input —punched tape read at 1,000 characters a second,
—punched cards read at 600 cards a minute,
—magnetic tape read at 8,500 characters a second.
Data output—tape punched at 300 characters a second,
—printed at 300 lines a minute with 140 characters a line,
—magnetic tape recorded at 8,500 characters a second.
Prototype under construction; completion in 1959.

**Powers-Samas Accounting Machines (Sales), Ltd.**
**Powers-Samas House, Holborn Bars, London, E.C.1.**

**Number of computer installations in operation in Europe by December, 1958:—24.**

POWERS-SAMAS ARE at present building one type of digital computer for commercial applications themselves and, in conjunction with Ferranti, Ltd., are producing a second machine, named Pluto. The former computer is known as the PCC or Programme Controlled Computer and is being manufactured on a production-line basis.

The PCC stems from the Electronic Multiplying Punch (EMP) developed by Powers-Samas. Primarily designed for accountancy applications, the computer can operate directly with decimal or sterling values. Design work on the PCC began in 1952 and the first installation was

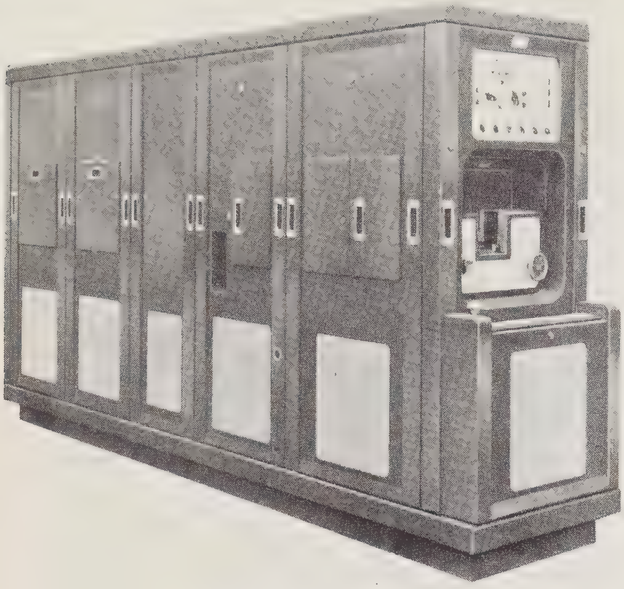


*Fig. 7. The Powers-Samas PCC or programme controlled computer. Over 130 PCC computers are on order*

completed in 1956. Powers-Samas state that over 130 PCC computers have been ordered and the intention is to produce these machines at the rate of one per week.

The Pluto data processing system was originally developed from the Ferranti Pegasus computer and can be equipped with a variety of punched card input, output and line printing units built by Powers-Samas. Data may also be read from, or recorded on, punched paper tape and magnetic tape.

Powers-Samas also build a high-speed line printer the Samastronic—that is used in many other data processing systems. The Samastronic prints 300 lines a minute and each line can consist of up to 140 characters.

Programmes to operate the Powers-Samas PCC are created permanently by making a pattern of electrical connections on a programme board. As many as four programme boards may be fitted, allowing programmes of up to 160 instructions to be performed. Data are presented to the computer on punched cards.

**Powers-Samas PCC Characteristics**

Number system—decimal or sterling.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
 + 0·5 millisecond (0·0005 second),
 6·5 to 65 milliseconds (0·0065 to 0·065 second),
 ÷ 25 to 150 milliseconds (0·025 to 0·15 second).
Type of instruction—interchangeable programme board.
Word length—16 sterling or decimal digits.
Quick access store—regenerative track on magnetic drum of 6 words capacity.
Main store—magnetic drum of 160 words capacity.
Data input —punched cards read at 120 cards a minute.
Data output—cards punched at 120 cards a minute.

Number of installations in operation in Europe by December, 1958:—24.

The Powers-Samas Pluto computer is classified as a data processing system and is intended for commercial and industrial work. All three standard means of presenting and recording computer information can be used—punched tape, punched cards and magnetic tape. The Samastronic line printer can also be supplied as a high-speed printing unit.

Information is stored internally on a magnetic drum, and nickel delay lines are fitted as quick access stores. Where magnetic tape is used, up to 16 magnetic tape units may be connected to the computer at one time.

**Powers-Samas Pluto Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average time for arithmetical operations:
 + 0·3 millisecond (0·0003 second).
 2 milliseconds (0·002 second).
 ÷ 5·5 milliseconds (0·0055 second).
Type of instruction—two address.
Word length —39 bits.
Immediate access store—nickel delay lines of 56 words capacity.
Main store—magnetic drum of 8,320 words capacity.
Data input —punched tape read at 300 characters a second.
 —punched cards read at 300 cards a minute.
 —magnetic tape read at 9,225 characters a second.
Data output—tape punched at 33 characters a second,
 —cards punched at 120 cards a minute,
 —magnetic tape recorded at 9,225 characters a second,
 —printed at 300 lines a minute, with 140 characters per line.

**Univac Computer Division.**
**Remington Rand, Ltd.**
**26 Kensington High Street, London, W.8.**

**Number of computer installations in operation in Europe by December, 1958:—1.**

Remington Rand, Ltd., is a British subsidiary of the Sperry Rand Corporation, of the United States. The Remington Rand organization in America has built punched card machinery for many years and, with the evolution of the electronic digital computer, the parent company designed and developed the Univac 1 computer. Univac is derived from a contraction of the phrase *Univ*ersal *A*utomatic *C*omputer.

Since the construction of Univac I, the company has built several other types of electronic digital computer, including an airline seat reservation data processing system based on the Univac file computer. At present, none of these computers is made in Great Britain, although two types within the Univac range are offered over here for sale or hire. These are the Univac File computer and the Univac II. The Univac File computer is the smaller of the two computing systems.

The company operates a computing service from London, based on a Univac I computer located at Frankfurt, Germany.

It is a fundamental point of Remington Rand design philosophy that, to obtain the most efficient operation of a computer, it is essential that the highest input reading speeds and data output recording speeds be used. For this reason magnetic tape is preferred.

As so many business data are already recorded on punched cards or punched tape, a number of automatic transcription units have been designed which automatically read the information from such documents, convert it into the appropriate code, and record it on magnetic tape. Similarly, a number of units are built which perform the reverse transcription automatically.

Univac II is a large, high-speed, general-purpose computer. A magnetic core store is fitted, the exact size of which can be varied to suit the particular application. The operating speed of the Univac II is faster than the Univac I, and so, too, are the speeds at which the associated input and output units work.

**Univac II Computer Characteristics**

Number system—binary excess-three code.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
+ 0·191 millisecond (0·000191 second).
× 0·333 millisecond (0·000333 second).
÷ 0·8 millisecond (0·0008 second).
Type of instruction—single address.
Word length—12 characters.
Main store—magnetic cores of from 2,000 to 10,000 words capacity.
Data input —magnetic tape read at 25,000 characters a second.
Data output—magnetic tape recorded at 25,000 characters a second.

In the Univac File Computer system there is a central computer, also a large capacity magnetic drum store and various auxiliary units. Two versions of this system are available, known as Model 0 and Model 1.

The Model 0 central computer is a plugboard machine. All instructions are established by wiring. The main store is a high-speed magnetic drum with 13 tracks; and 120 characters can be accommodated on each track.

Model 1 central computer can be operated from a plugboard programme or an internally stored programme, or a combination of both. A high-speed magnetic drum with 107 tracks, on each of which 120 characters can be recorded, is used for the main information store.

A general storage system to provide extra information storage capacity is contained in separate cabinets and can be connected to the central computer. The cabinets contain from 1 to 10 magnetic drums for the Model 0 computer or from 1 to 33 magnetic drums for the Model 1 computer.

**Univac File Computer Characteristics**

Number system—binary excess-three code.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:
+ 2 milliseconds (0·002 second).
26 milliseconds (0·026 second).
÷ 33 milliseconds (0·033 second).
Type of instruction—three address.
Immediate access store—magnetic cores of 240 characters capacity.
Main store —magnetic drum of 12,840 characters capacity. (Model 1.)
General store—magnetic drums (Model 0, 180,000 to 1,800,000 characters; Model 1, 180,000 to 5,940,000 characters).
Data input —keyboard.
—punched tape read at 200 characters a second.
—punched cards read at 300 cards a minute.
—magnetic tape read at 10,400 characters a second.
Data output—typewriter at 8·5 characters a second.
—cards punched at 150 cards a minute.
—tape punched at 60 characters a second.
—magnetic tape at 10,400 characters a second.
—printed at 600 lines a minute with 130 characters per line.

**Standard Telephones and Cables, Ltd.**
**Connaught House, 63 Aldwych, London, W.C.2.**

**Number of computer installations in operation in Europe by December, 1958:—13.**

STANDARD TELEPHONES build an electronic digital computer known as the Stantec Zebra. This was designed and developed jointly by the Standard Telephones and Cables, Ltd., and the Netherlands Postal and Telecommunications Services. For special applications, variations of the standard version are constructed.

The Stantec Zebra is a general-purpose digital computer. The main information store is provided on 256 tracks of a magnetic drum. Regenerative tracks on the magnetic drum are used as quick access stores.

Input data are presented on punched tape. One reading unit is normally provided, although the design has been arranged to allow for more reading units to be associated with the computer if this is required. Two output units may be operated—a tape punch and a teleprinter.

The following facilities may also be provided when specified: immediate access storage up to 256 words capacity on magnetic cores; punched card reading and punching units; and multiple tape punches or teleprinters for recording results.

**Stantec Zebra Computer Characteristics**

Number system—binary.
Mode of operation of arithmetic unit—serial.
Average times for arithmetical operations:—
+ 0·312 millisecond (0·000312 second).
11·0 milliseconds (0·011 second).
÷ 35·0 milliseconds (0·035 second).
Type of instruction—two address.
Word length—33 bits.
Quick access store—regenerative track on magnetic drum of 12 words capacity.
Main store—magnetic drum of 8,192 words capacity.
Data input —punched tape read at 200 characters a second.
Data output —tape punched at 50 characters a second.
—printed at 10 characters a second.

*Fig. 8. A Stantec Zebra computer in use at the Liverpool offices of J. Bibby & Sons, Ltd., on mixing problems*

# Wage accounting and

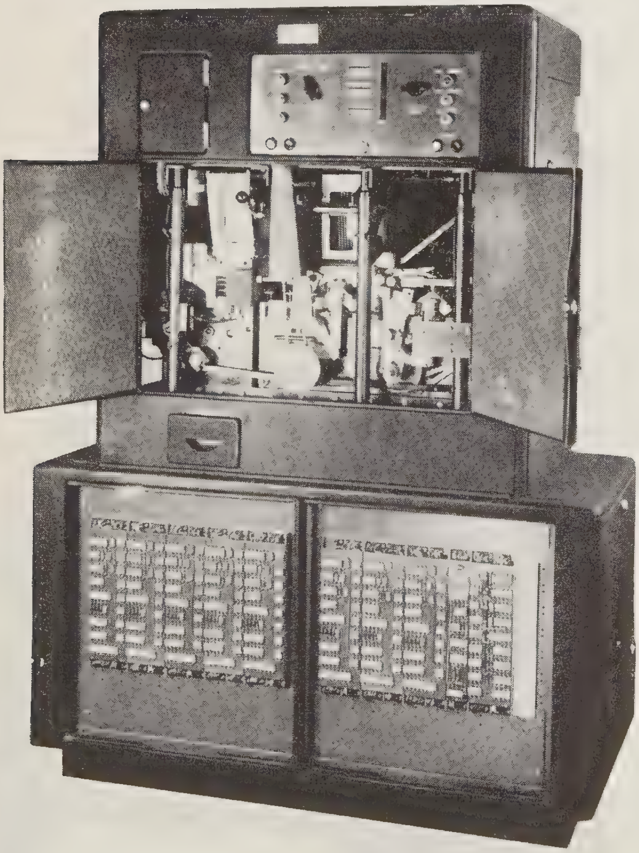
## PERFORMED ON A PUNCHED CARD SYSTEM THAT

BY A. A. MCPHIE*

Calculating the wage and bonus earnings of employees and the appropriate costs to be charged to each production order—this is part of the work performed by the Sperry Gyroscope Co., Ltd., with the aid of an electronic calculator. A number of other administrative tasks are also undertaken in their machine accounting department, such as the reassessment of standard costs, material accounting, and keeping purchase ledgers and personnel records. All these operations are carried out, largely automatically, on the punched card installation.

WHILE it is generally agreed that to employ electronic calculation in accountancy brings many advantages, it is not widely appreciated that there are machines besides electronic digital computers which can perform this work. The benefits of electronic calculation can be obtained by using a simpler and much less expensive piece of equipment — the electronic calculator. Machines of this type cost approximately £7,500 and can perform all the standard arithmetical operations. They will carry out this work quickly and efficiently and can be incorporated easily into an existing punched card installation. All information is presented to the calculator and answers are received from it punched into machine cards of the standard size.

*Fig.* 1. *Powers-Samas Emp electronic calculator performs calculations at a speed of* 120 *a minute*



These machines have electronic circuits for calculating, but only the minimum capacity for storing information and the minimum of control facilities. One calculator of this type, the Powers-Samas Emp (derived from *e*lectronic *m*ultiplying *p*unch), can handle up to six factors in any one calculation arranged in the form

$$X = A \times B + \left[C\,(D \pm E \pm F)\right].$$

Such calculations are performed at a speed of 120 a minute. One card is used for each calculation and the answer is punched into the same card that carries the factors.

The Powers-Samas Emp functions in the following manner. Punched cards containing the information to be processed are loaded into a magazine at one end of the machine. They are fed, in sequence, from the magazine to the first sensing station. Here any factor that will remain constant for a number of subsequent calculations is read from the card. For example, should there be a sequence of cards where the

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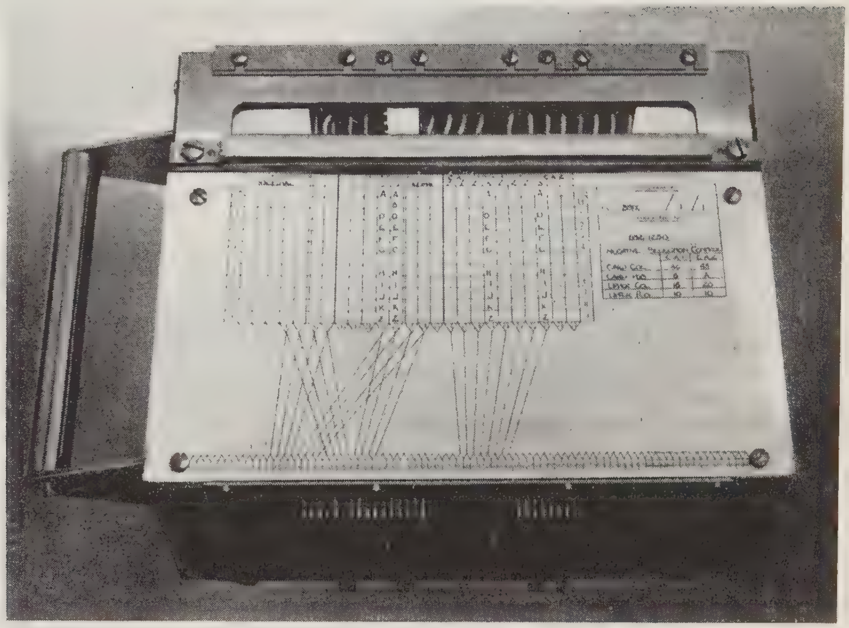
*Mr. McPhie is a member of Powers-Samas Accounting Machines, Ltd.

# labour costing

## INCORPORATES AN ELECTRONIC CALCULATOR



*Figs. 2 and 3. The particular calculations performed are controlled by connection units, such as this, which are inserted into the calculator before a computing run*

cost per item or some other factor remains the same, but where different quantities are recorded on each card, a rate-card containing this constant factor is passed through the calculator first. When the rate-card—identified by a special punched hole—arrives at the first sensing station, the constant factor is read from the card and recorded in the machine circuit before the card is passed through to the output magazine. Factors on all subsequent cards are then multiplied by this constant until a new rate-card is introduced into the system.

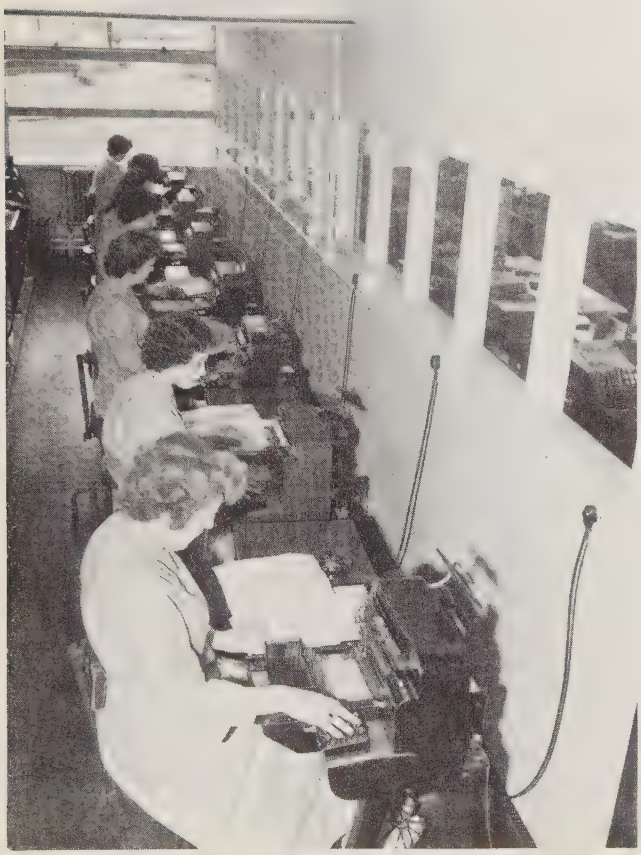
At the second sensing station in the calculator the main data to be processed are read mechanically by selecting-pins which project through the perforations in the card. These pins operate electrical switches that initiate the pulse-trains used to perform the calculation. The answer derived is fed to a mechanical store

located at a third machine station. Here it is punched into the appropriate card when it arrives at this station, provided that an intermediate verification, performed while the card is moving from the second to the third machine station, confirms that the answer obtained is correct. To indicate that it is correct, a signal hole is punched into the card simultaneously with the answer. The completed card is then ejected into the output magazine.

Verification may cause the answer to be cancelled because, for example, factors beyond the capacity of the machine have been read from the card. Alternatively, the answer can be cancelled intentionally by punching a hole in a special position on the card, as, for instance where there is a card in the pack for which a particular calculation is not required.

At the conclusion of a run, three counters on the control panel of the calculator show, respectively, the number of cards passed through that do not contain answers, the number of cards in each batch, and the gross total of all cards processed. The readings on these dials obviously affect the procedure adopted at the end of a run. If the first counter registers zero, the cards are passed on to the next operation. Should the counter show that some cards have been passed through that do not contain answers, the incompleted cards are extracted. To do this, the pack of cards is held up to the light, whereupon any cards that do not contain the special verification hole can be located easily and removed.

*Fig. 4. Transcribing the basic data from the factory documents into punched cards in the machine accounting department*



Programming is not required with calculators of this type. Calculations are controlled by a connection unit which is inserted into the calculator by the operator. This unit specifies how the various factors entered in the card are to be processed and the columns into which the answer is to be punched. Connection units are mechanical devices which operate a number of electrical switches that determine the type of calculation performed. These units are built when the calculator is being prepared to accommodate a particular job and the units are retained until the job is either dispensed with or altered in some way.

Electronic calculators of this pattern can be integrated with orthodox punched card equipment and the resultant combination makes a fast, flexible and versatile data processing installation with which quite a high degree of mechanization can be attained.

The Sperry Gyroscope Co., Ltd., have such an installation and have, in fact, been using punched card machines since 1945. Their installation is extensive. In addition to a Powers-Samas Emp they have four tabulators, three sorters, two interpreters, an interpolator, two autoverifiers, a reproducer and 16 universal key punches, all functioning with 65-column cards.

Over 4,000 people are employed at the main factory of the company at Brentford and its several satellites. A wide range of precision products are manufactured, principally for the aircraft industry. Many of the components are produced individually or in small batches, and the nature of this work demands flexibility in the shops, interchangeability of operatives and a versatile accounting system that can accommodate the many changes that arise. These factors, and, of course, the additional book-keeping work in connection with P.A.Y.E. and National Insurance contributions, influenced the decision to introduce punched card accounting machines in 1945 and later to obtain an electronic calculator.

One of the many tasks performed with the aid of this equipment is wage accounting. Acquisition of the raw data for this particular work begins with a document known as the production order. It is the source document with which all subsequent recordings are identified. Relevant

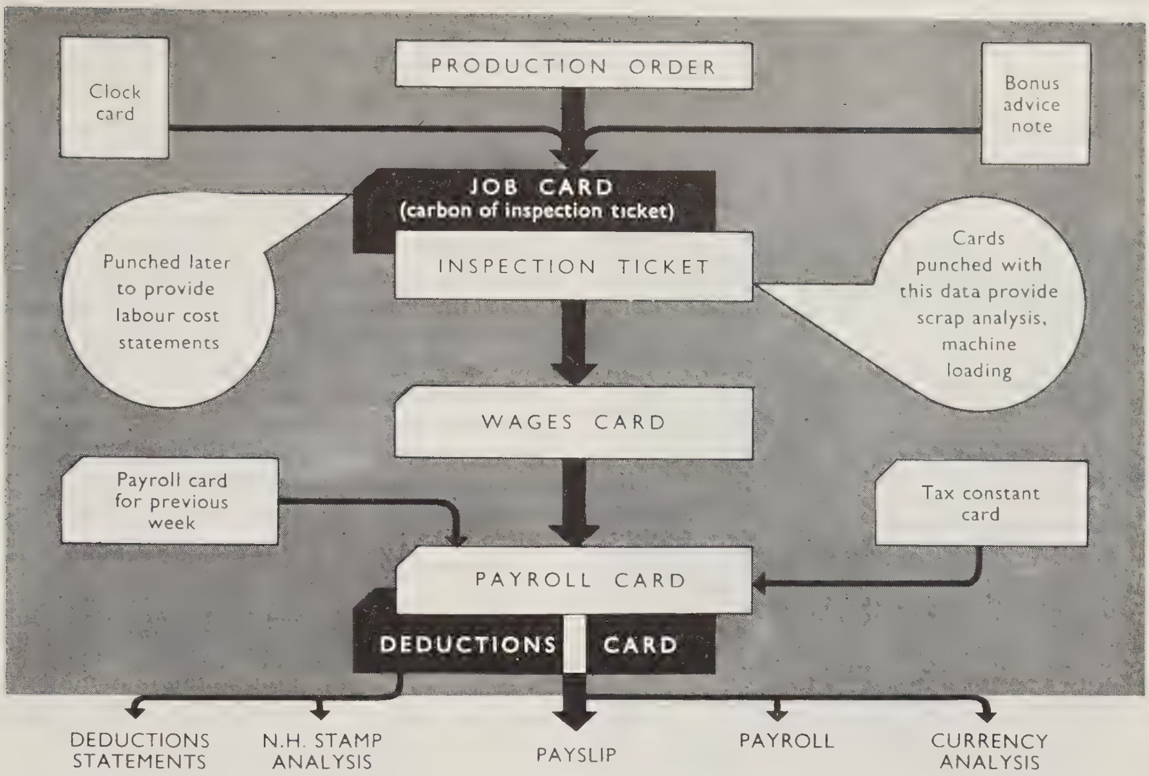


*Fig. 5. Data processing sequence indicating the source documents from which the basic data are obtained and the final documents produced*

data from the production order are entered on to another document called an authority to manufacture. This authority is prepared in the production-control department and, accompanied by the drawings and process layouts, is routed through the planning, production and progress sections to the point in the works where the operation is to be performed.

An operative is given the authority to manufacture and he contacts a time-clerk, who prepares a job-card and an inspection-ticket: the job-card is a carbon copy of the inspection-ticket. Both documents carry a similar serial number and the data entered from the authority to manufacture are the part number, description, production order number, operation, quantity to be made, unit time allowed and, from the employee, his clock number, name and department. The time-clerk also records, on the job-card only, the time the work is started.

On and off times are recorded on the job-card each day, until the work is completed. The total hours worked up to the end of the week are entered on the card and the card is sent to the machine accounting department. If the job continues over a weekend, the total hours worked are carried forward on to a continuation card. When the job is completed the last continuation card will, of course, contain the grand total of hours worked.

In addition, each week a bonus advice note is prepared for every employee, including those working on non-bonus jobs. This note is held by the time-clerk. Information on this document is printed by an addressing machine and includes the employee's consolidated and special rates of pay. At the weekend the totals of ordinary and overtime hours, as recorded on the clock-card, are also entered on the bonus advice note and the completed document is sent to the machine accounting department.

When the operator has finished the job, the work, accompanied by the inspection-ticket, is passed to the inspection department. Inspection enter on the ticket the number of components accepted and the ticket is then returned to the time-clerk, who forwards it to the machine accounting department.

In the machine accounting department there will now be three documents for all jobs that have been completed, but only two documents, the job-cards and bonus advice notes, for those jobs still in progress. Inspection-tickets and job-cards for completed jobs are now married manually by reference to the serial number. The quantity accepted—as recorded on the inspection-ticket—is entered manually on the job-card and bonus is computed from—

Unit time allowed × quantity = total time allowed (T1)
T1—time taken = time gained or lost (T2)
T2 (if positive) × bonus rate = bonus to be paid.

Bonus earned is entered manually on the job-card and also on the bonus advice note. It is, of course, possible to have several bonus entries on one advice note when the employee has worked on several jobs. Conversely, if he has not completed a job on which bonus is payable there will be no entry.

This operation completes the initial manual work of gathering the raw data for wage accounting and labour costing.

In common with other types of work rigorous control has to be exercised over machine calculations to ensure that the results obtained are accurate. A suitable way of achieving this is, of course, to compare totals compiled by two different methods. Consequently, the initial work on the raw data is to set up suitable control totals. These totals are prepared for groups of approximately 300 employees and separate totals are derived for each factor that goes to make up their net pay—such as basic wage, overtime and bonus.

At the conclusion of all subsequent calculations the various totals of each factor for the group of employees that constitutes the control unit are compared with these control totals. Any discrepancy will indicate that an error has been made. This, obviously, must be corrected before the data are passed on to the next stage of the calculation. By such means a continuous check can be maintained on the accuracy of each phase of the calculation.

In the machine accounting department the initial task is to transcribe the data into punched cards and the first cards to be punched are the wages cards. Basic data are obtained from the documents already mentioned such as the bonus advice note. These data are entered into the cards manually on an automatic key punch. Information punched into each wages card includes:–

| | | |
|---|---|---|
| Column | 1 | type of card |
| ,, | 2– 3 | week number. |
| ,, | 4–11 | department and clock number. |
| ,, | 12–15 | total hours worked. |
| ,, | 16–19 | rate of pay for total hours. |
| ,, | 20–23 | uplift hours for overtime. |
| ,, | 24–27 | rate for uplift hours. |
| ,, | 38–41 | other payments. |
| ,, | 42–45 | bonus payments. |

Accuracy of transcription is checked by a second operator who repeats the operation. The second set of round holes punched are displaced a small distance vertically in relation to the first set of holes. Consequently, identical recordings produce oval perforations. The cards are then passed through another machine—the automatic verifier—which places a coloured

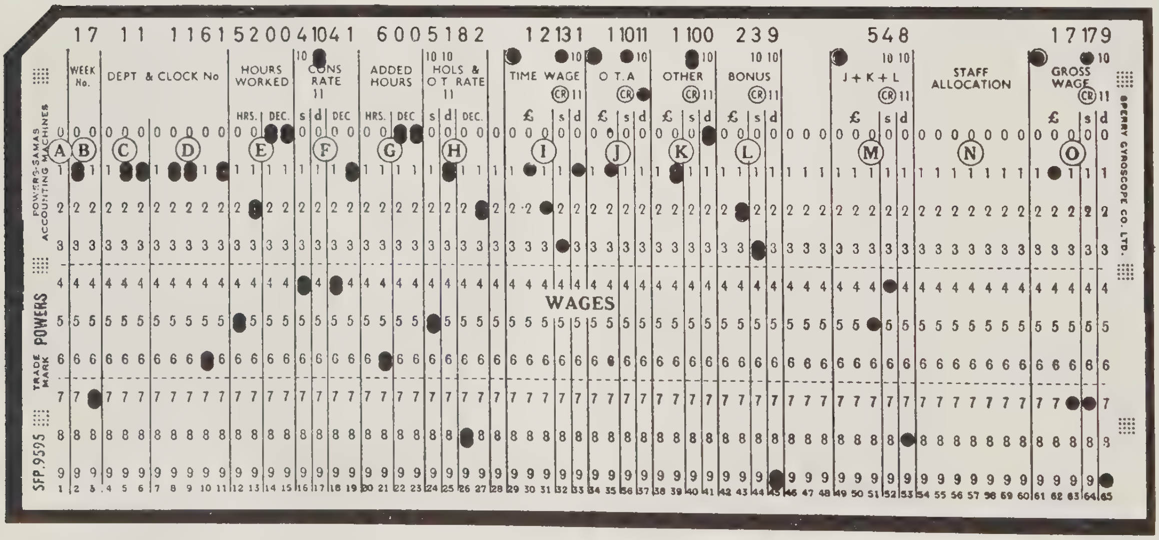


*Fig. 6. Wages card. Information punched in the columns is printed along the top of the card*

marker card adjacent to any card containing round holes. Round holes, of course, indicate that an error has been made as the two operators must have depressed different keys. Incorrect cards, identified by the marker cards, can then be selected quickly from a complete pack and are replaced by new cards correctly punched.

At the next stage of the data processing sequence the electronic calculator is used. In two operations, the hours worked (cols. 12–15) are multiplied by the rate (16–19) to produce the time wage (29–33); and the uplift hours (20–23) are multiplied by the uplift rate (24–27) to produce the overtime allowance (34–37). Calculations proceed at the rate of 120 per minute regardless of the number of digits involved and whether there are sterling factors in the calculation or only decimal.

In the next operation the calculator cross-adds the factors just derived to the other payments (38–41) and the bonus (42–45). As three factors can be accepted at one sensing on the machine used by Sperry, overtime allowance, other payments and bonus are added together first to produce a partial result (49–53); then, during a second run, this result is added to the time wage (29–33) to produce the gross wage. This result is punched in columns 61–65 and concludes the preparation of the wages card.

**Negative factors**

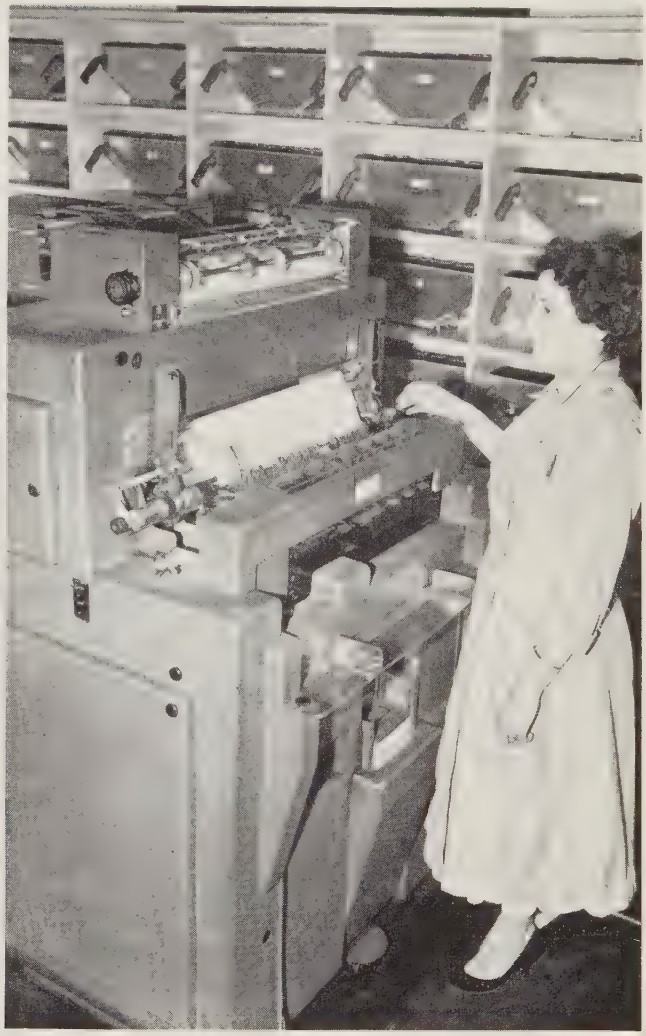
Throughout these runs, the machine will automatically add the three factors together unless a signal hole is detected in the upper part of columns 32, 36, 40, or 44. These holes cause the machine to subtract the factors over which they appear as opposed to adding. As will be seen from the illustration of the wages card, subtraction signal hole positions are indicated by CR (Fig. 6).

The wages cards are next fed through a tabulator. All the details punched into each card are printed out, certain data are added and totals for those factors making up the gross wage of the control unit are produced. These unit totals are then agreed with those control totals derived previously. By the agreement of two sets of figures produced by different procedures the accuracy of both is proved. Tabulations from the wages cards also provide an analysis of the gross wages earned.

The gross wage for each employee having been computed the next step is to calculate the net pay. A payroll card is used for this work and all the basic data necessary for the calculation are punched into the cards automatically by a reproducing punch—no manual transcriptions are performed. A reproducing punch can copy information from an existing set of punched cards into new cards, one for one, at the rate of 200 a minute. Certain data already recorded in the payroll cards of the previous week are entered in the payroll cards being prepared for the current week. These include:—

| | |
|---|---|
| Department and clock number | (cols. 4–11) |
| Tax code number | (cols. 12–14) |
| Gross wages brought forward | (cols. 27–32) |
| Weekly tax-free income | (cols. 15–17) |
| Tax brought forward | (cols. 39–42) |
| Standard deductions | (cols. 56–60) |

*Fig. 7. Data contained on punched cards are automatically printed, in appropriate documentary form, on a tabulator*



The card number (1) and week number (2–3) are also automatically punched into every card during the data reproducing operation.

An interpolator is next used to compare the reproduced payroll cards with the wages cards for the current week to ensure that there is one of each for every employee. If an employee has left and has no payroll card but is due for bonus earned, a dummy payroll card containing identifying data only must be included. Now, with the cards paired, the hours worked and the gross wage for the current week are reproduced automatically from the wages card into the corresponding payroll card.

Next, the calculator is used to compute the gross wage to date (33–38) by adding the gross wage of the current week (22–26) to the gross wage brought forward (27–32). Taxable income to date (47–52) is obtained by multiplying the weekly tax-free income (15–17) by the week number (2–3) and deducting the product from the gross wage to date.

Calculation of the amount of tax due begins with the preparation of a set of tax-constant cards. Each of these cards is punched with a previously calculated factor which, when applied to the taxable income to date, gives the tax due to date. Payroll cards are sorted in order of taxable income and the cards for all employees within a specified taxable income range will be preceded by the tax-constant card appropriate to that range.

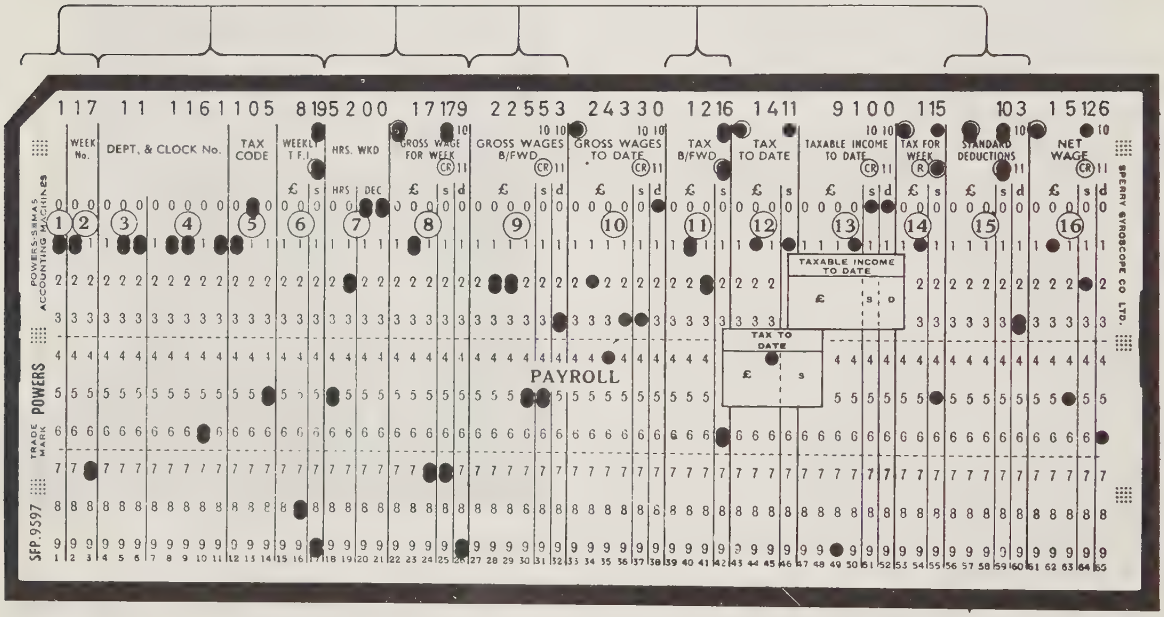
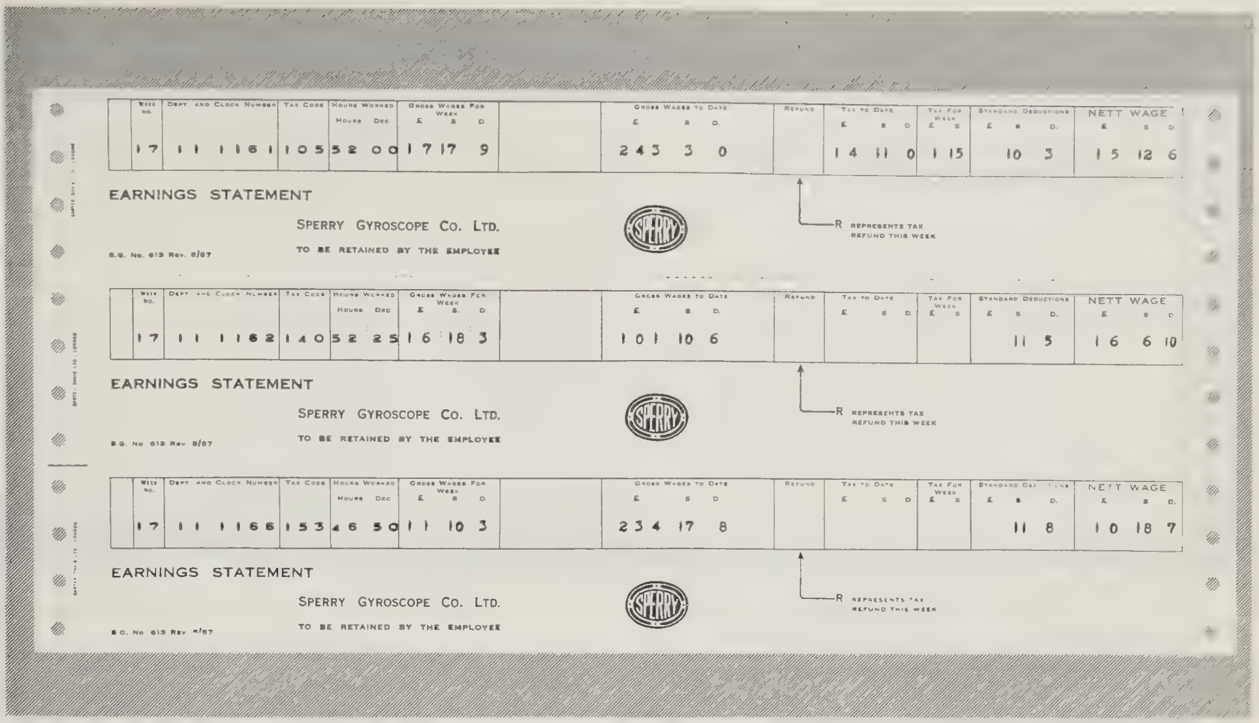


*Fig. 8. Payroll card. All information in the columns indicated by the brackets is automatically punched into the card by a reproducing punch, operating at 200 cards a minute*

When the cards are fed into the calculator the value on the tax-constant card is taken into an information store and applied to the taxable income to date recorded on the succeeding cards. This continues until a new tax-constant card is detected. The computed result, that is the tax to date, is punched into columns 43–46 of the card. Tax brought forward (39–42) is deducted from the tax to date and the difference, tax due, is punched into columns 53–55.

Finally, the net pay (61–65) is obtained by deducting from the gross wage the tax due together with any standard deductions. A standard deductions card is created for every employee and is used repeatedly while the relevant conditions of his employment continue unchanged. New cards are added for new entrants and existing ones are removed as employees leave. Amendments to the file of standard deductions cards are made from time to time as necessary.

This concludes the operations on the payroll card—which are automatic. The entire calculations needed to derive the net pay for 40 employees are completed in three minutes. This rate does not, of course, include any



| Week No. | Dept and Clock Number | Tax Code | Hours Worked Hours Dec | Gross Wages for Week £ s d | | Gross Wages to Date £ s d | Refund | Tax to Date £ s d | Tax for Week £ s | Standard Deductions £ s d | NETT WAGE £ s d |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 11 1161 | 105 | 52 00 | 17 17 9 | | 243 3 0 | | 14 11 0 | 1 15 | 10 3 | 15 12 6 |

EARNINGS STATEMENT

SPERRY GYROSCOPE CO. LTD.

TO BE RETAINED BY THE EMPLOYEE

S.G. No. 613 Rev. 8/57

R REPRESENTS TAX REFUND THIS WEEK

| Week No. | Dept and Clock Number | Tax Code | Hours Worked Hours Dec | Gross Wages for Week £ s d | | Gross Wages to Date £ s d | Refund | Tax to Date £ s d | Tax for Week £ s | Standard Deductions £ s d | NETT WAGE £ s d |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 11 1162 | 140 | 52 25 | 16 18 3 | | 101 10 6 | | | | 11 5 | 16 6 10 |

EARNINGS STATEMENT

SPERRY GYROSCOPE CO. LTD.

TO BE RETAINED BY THE EMPLOYEE

S.G. No. 613 Rev. 8/57

R REPRESENTS TAX REFUND THIS WEEK

| Week No. | Dept and Clock Number | Tax Code | Hours Worked Hours Dec | Gross Wages for Week £ s d | | Gross Wages to Date £ s d | Refund | Tax to Date £ s d | Tax for Week £ s | Standard Deductions £ s d | NETT WAGE £ s d |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 11 1166 | 153 | 46 50 | 11 10 3 | | 234 17 8 | | | | 11 8 | 10 18 7 |

EARNINGS STATEMENT

SPERRY GYROSCOPE CO. LTD.

TO BE RETAINED BY THE EMPLOYEE

S.G. No. 613 Rev. 8/57

R REPRESENTS TAX REFUND THIS WEEK

*Fig. 9. Payslips automatically printed by the tabulator*

allowance for card handling or machine setting. When the payroll cards are completed, all the details of pay for each employee have been ascertained, and verified, and the next stage is to present this information in legible form. This operation is performed automatically on a tabulator which prints a list of the data contained in the cards. Totals and sub-totals are printed for each department. Agreement of these figures with the control figures ensures the accuracy of the calculations performed and the completeness of the record.

Payslips which contain all the basic details making up the net pay are distributed to the employees, accompanied by bonus advice notes which give additional information concerning bonus pay.

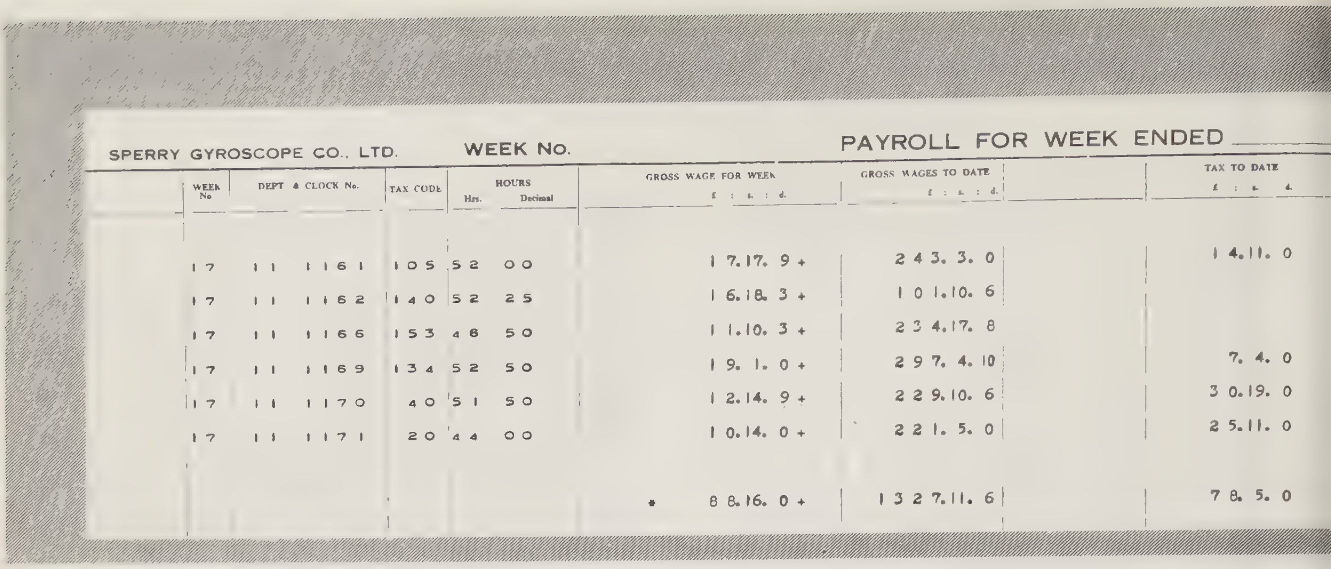
Various other documents and records are also produced from the payroll cards, one of which is an analysis of the currency required to make up the pay. This work is done in a tabulator, which breaks down the net amount to be paid to each employee into figures for notes, silver and coppers and, at the end of each departmental list, shows the total values needed of each unit of currency. Similarly, insurance-stamp requirements are analysed. This latter tabulation is taken along to the local National Insurance office, where the franking machine of the company is set to the necessary values.

Another ancillary document which is produced automatically and has proved extremely valuable, is a continuous record on a machine card (the record card) of the details of each individual's pay. Record cards are interleaved with the payroll cards, one for one, by a verifying machine. The combined pack is then passed through an interpreter which reads the perforations on the payroll card and prints the information on the record card that follows. Each week the record cards are filed to maintain a continuous register of all those items, such as basic wage, bonus, overtime and so on that go to make up the gross wage of each employee.

Records covering 17 weeks can be printed on one card. Payroll information listed in this way is extremely useful as it enables queries raised by employees to be answered quickly. To obtain such information direct from the payrolls might otherwise occupy many hours.

Payrolls for weekly and monthly-paid staff are compiled in a similar manner though the task is simpler. By the use of code numbers instead of names, punched cards lend themselves to the maintenance of the confidential nature of this work.

All the calculations needed to compile the payroll having been made, the same financial information can now be used in another data processing sequence to assess the costs of



SPERRY GYROSCOPE CO., LTD. WEEK No. PAYROLL FOR WEEK ENDED

| WEEK No | DEPT & CLOCK No. | | TAX CODE | HOURS | | GROSS WAGE FOR WEEK | GROSS WAGES TO DATE | TAX TO DATE |
|---|---|---|---|---|---|---|---|---|
| | | | | Hrs. | Decimal | £ : s. : d. | £ : s. : d. | £ : s. d. |
| 17 | 11 | 1161 | 105 | 52 | 00 | 17.17. 9 + | 243. 3. 0 | 14.11. 0 |
| 17 | 11 | 1162 | 140 | 52 | 25 | 16.18. 3 + | 101.10. 6 | |
| 17 | 11 | 1166 | 153 | 46 | 50 | 11.10. 3 + | 234.17. 8 | |
| 17 | 11 | 1169 | 134 | 52 | 50 | 19. 1. 0 + | 297. 4. 10 | 7. 4. 0 |
| 17 | 11 | 1170 | 40 | 51 | 50 | 12.14. 9 + | 229.10. 6 | 30.19. 0 |
| 17 | 11 | 1171 | 20 | 44 | 00 | 10.14. 0 + | 221. 5. 0 | 25.11. 0 |
| | | | | | | * 88.16. 0 + | 1327.11. 6 | 78. 5. 0 |

production. Labour costs can be extracted from the data on the job-card that was originally used as a source document for the wage-calculation sequence. Information was entered on the job-card in writing although, in fact, it is a standard 65-column machine card. This written information is now punched into the card and it becomes a labour cost-card bearing the following data:—

Type of card.
Week number.
Department and employee's clock number.
Part number.
Account code, or production order number.
Gross wage.
Labour code (machining, assembly, etc.).

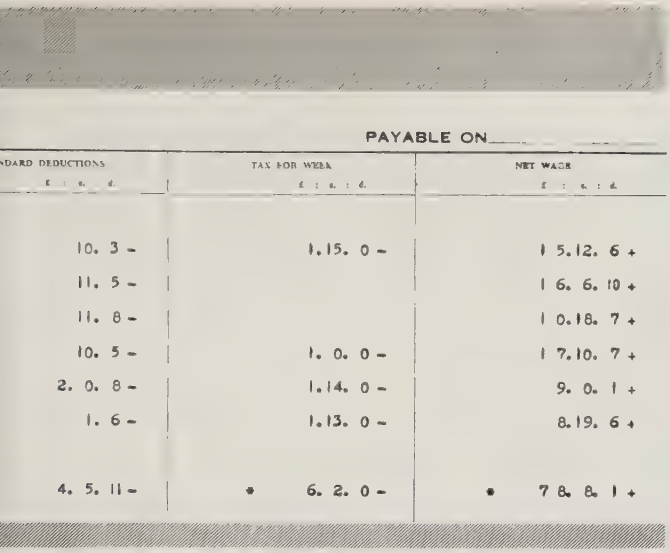
To obtain true cost statements, account must also be taken of indirect labour and cards are punched for this class of work as well. All labour cost-cards are tabulated and agreed with the predetermined control figures, thus inflexibly tying the financial records with the production costs.

Material costs also have to be recorded before final cost statements can be compiled. Material is charged to a production order at a standard price and requisition notes at this price are the basis for punching cards to compile the charges.

The various labour and material cost-cards are accumulated daily and, at weekly intervals, are sorted by production order number. There are approximately 14,000 of these cards each week and they represent every direct item of expenditure made on every production order during the week. Previous expenditure on labour and material is recorded in summary cards. There is one summary card for each production order and up to 12,000 may be active. Expenditure recorded on these summary cards combined with that on the current week's labour and material cost-cards represents the expenditure, to date, on work in progress.

Two main tabulations are prepared from these cards, one showing the expenditure to date on all production orders on which there has been action during the current week and the other tabulation lists the final cost totals for completed orders. In the first procedure the summary cards are compared with the weekly batch of material and labour cost-cards in an interpolator. Only those production order summary cards are extracted for which there are current weekly cost-cards; the purpose of this operation is to reduce tabulating time. Quite often, there may have been no costs incurred against as many as 10,000 of the orders, so there is no object in tabulating summary cards that will give only a repetition of the previous week's cost figures. When the tabulation of active orders is made the tabulator is coupled with a summary punch, which automatically produces a new summary card detailing the new totals for labour and material costs chargeable against each production order. This up-dated summary card is placed in the work in progress file along with those cards for the previous weeks

When an order is completed, the machine accounting department is advised and all cards relating to that order are tabulated to produce a final cost statement. This statement shows the expenditure upon each class of labour—fitting, machining, assembling and so on—and also the



PAYABLE ON

| NDARD DEDUCTIONS £ : s. d. | TAX FOR WEEK £ : s. : d. | NET WAGE £ : s. : d. |
|---|---|---|
| 10. 3 - | 1.15. 0 - | 15.12. 6 + |
| 11. 5 - | | 16. 6. 10 + |
| 11. 8 - | | 10.18. 7 + |
| 10. 5 - | 1. 0. 0 - | 17.10. 7 + |
| 2. 0. 8 - | 1.14. 0 - | 9. 0. 1 + |
| 1. 6 - | 1.13. 0 - | 8.19. 6 + |
| 4. 5. 11 - | * 6. 2. 0 - | * 78. 8. 1 + |

*Fig. 10. Part of a payroll produced on the tabulator. Totals and sub-totals for departments are derived automatically by summing registers in the tabulator*

expenditure on materials. Tabulation is done in such a way that overheads can be allocated as a percentage of each sub-total. Total cost figures are compiled manually from these sub-totals and can be compared with the original estimates or actual selling prices for consideration of the margins obtained.

An interesting ancillary operation arises concerning the assessment of the standard prices charged for materials used during manufacture. The standard price card-file contains one card for each class of material stocked. As new supplies are received, cards are punched with the information on the goods-received advice note. These cards are duplicated—a second set being prepared automatically by a reproducing punch. One set is used for the financial control of the stock accounts and the other set is used to establish variations in material prices from the accepted standard. The actual price and the standard price are compared in the calculator and a new card is punched detailing any variation in price from the standard.

A tabulation made from these variation cards gives the costing department rapid notification of changes to be made in the cost of finished orders that include new-priced materials. It also supplies the information needed to keep the standard-price file up to date.

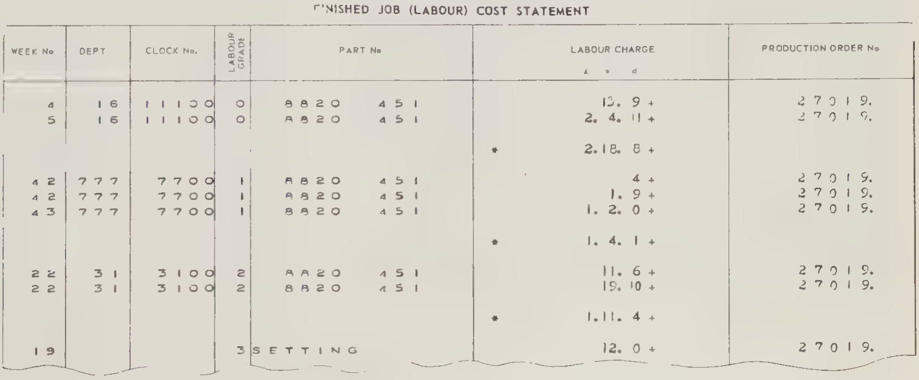
Another example of the valuable information that is obtained for management from the raw data used initially for wage accounting is a comprehensive analysis of machine-loading and scrap. These data are obtained by the orthodox tabulation of cards punched with the information recorded on the inspection-tickets.

Sperry's machine accounting installation performs a number of other tasks that include materials accounting, and the maintenance of purchase ledgers and personnel records. These jobs are carefully integrated into the main data processing sequence in which the payroll has the tightest time schedule. Very careful planning is required to cover this range of work and each job has been time-studied to ensure that it can be fitted into the operating schedule satisfactorily. Comprehensive instructions have been compiled, and an operator can take over any task with a minimum of supervision.

It is impossible to say what savings have been made by the adoption of these methods, because they are so far-reaching, but it is clear that to revert to manual methods would necessitate a very considerable increase in the clerical staff.

The author wishes to acknowledge the considerable assistance which Sperry Gyroscope Co., Ltd., have given him in the preparation of this article.

*Fig. 11. By analysing the data obtained during the calculation of the payroll in a different way, finished job cost statements can be produced*



FINISHED JOB (LABOUR) COST STATEMENT

| WEEK No | DEPT | CLOCK No. | LABOUR GRADE | PART No | LABOUR CHARGE £ s d | PRODUCTION ORDER No |
|---|---|---|---|---|---|---|
| 4 | 16 | 11100 | 0 | 8820 451 | 13. 9 + | 27019. |
| 5 | 16 | 11100 | 0 | 8820 451 | 2. 4. 11 + | 27019. |
| | | | | | * 2.18. 8 + | |
| 42 | 777 | 7700 | 1 | 8820 451 | 4 + | 27019. |
| 42 | 777 | 7700 | 1 | 8820 451 | 1. 9 + | 27019. |
| 43 | 777 | 7700 | 1 | 8820 451 | 1. 2. 0 + | 27019. |
| | | | | | * 1. 4. 1 + | |
| 22 | 31 | 3100 | 2 | 8820 451 | 11. 6 + | 27019. |
| 22 | 31 | 3100 | 2 | 8820 451 | 19. 10 + | 27019. |
| | | | | | * 1.11. 4 + | |
| 19 | | | 3 | SETTING | 12. 0 + | 27019. |

# High-speed printing

## THE XERONIC PRINTER

*operates at 1,500 lines a minute*

*prints lines up to $11\frac{1}{2}$ inches in width that can contain 128 characters*

*automatically prints the output data in the correct position on pre-printed stationery*

* * * * * *

In the near future a developed version of the machine is to be built and . . .

*the printing speed will be raised to 3,000 lines a minute*

*the form will be printed simultaneously with the data, eliminating the need for pre-printed stationery*

*automatic selection of the form to be printed will also be possible*

*duplicate or quadruple copies will be produced simultaneously, with the additional convenience that the printing of selected items of information can be excluded, at will, from certain of the copies*

*microfilmed master records of the output data will also be produced simultaneously*

XEROGRAPHY is a photo-electric technique originally developed to print facsimiles of documents. It is now being used as a method of printing computer output data. A prototype machine, called the Xeronic, has been built and is in operation.

The main advantage of xerography for computer output printing is that numerical and alphabetical characters can be produced clearly and at very high speed. At present, printing-rates are 5,000 characters a second and 1,500 lines a minute, but it is expected that shortly the printing speed will be raised to 3,000 lines a minute. The printer can be operated directly by the computer or by data recorded on some output medium such as magnetic tape or punched cards.

Magnetic tape is used to operate the prototype machine, which prints characters on normal pre-printed stationery, 15in in width, that is fed through the machine continuously at the rate of 20ft a minute. Lines up to a maximum width of $11\frac{1}{2}$ inches can be printed.

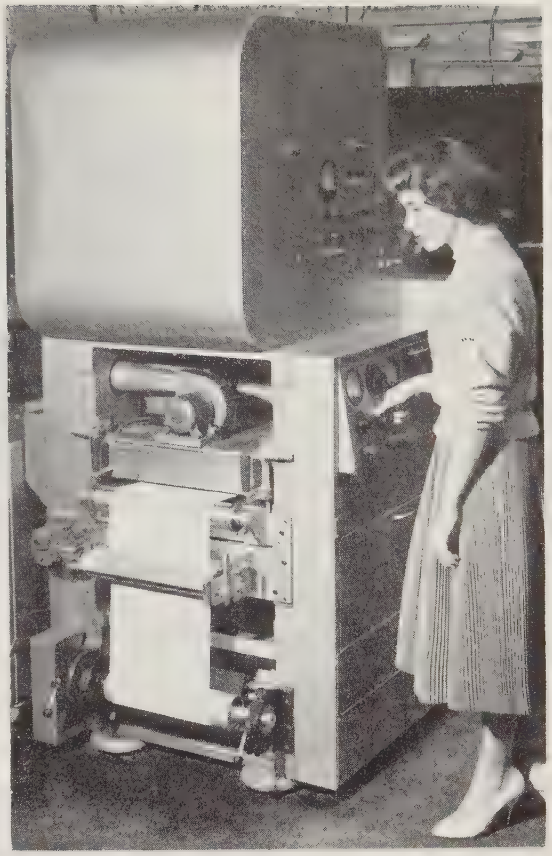
Characters are entered in the appropriate places on the pre-printed forms, but soon it will be possible for the form itself to be printed xerographically at the same time as the output data. With this new development, provision will also be made for the automatic selection of the design of form to be printed—the particular form that suits the data. These forms can be up to 13 inches in width.

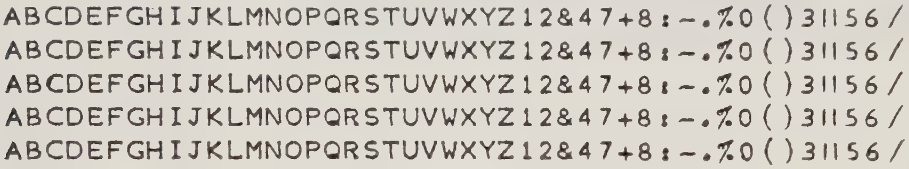
Another development will make it possible for copies of the output data to be produced simultaneously with the primary document. For this purpose a machine is being built to accommodate reels of paper 26in in width, which will allow a maximum form width of 24in.

**Photo-electric techniques applied as the means whereby data are printed out either directly from the computer or through the medium of magnetic tape, punched cards or punched tape**

On this, two identical columns 11½in in width or, alternatively, four columns each 5½in wide, can be printed simultaneously side-by-side. In the latter case, although the data for all four columns are supplied from a common source, a selective control on the printer will allow specific items of information to be excluded, if desired, from one pair. Similarly with the two 11½in lines, selected information can be suppressed, at will, from the second column.

A microfilming unit can be fitted to the Xeronic printer to make a microfilm master record for the files, this simultaneously with the documents required for immediate use. Therefore, further copies of the original documents can be produced at any time by normal microfilming techniques.





ABCDEFGHIJKLMNOPQRSTUVWXYZ12&47+8:-.%0()31156/
ABCDEFGHIJKLMNOPQRSTUVWXYZ12&47+8:-.%0()31156/
ABCDEFGHIJKLMNOPQRSTUVWXYZ12&47+8:-.%0()31156/
ABCDEFGHIJKLMNOPQRSTUVWXYZ12&47+8:-.%0()31156/
ABCDEFGHIJKLMNOPQRSTUVWXYZ12&47+8:-.%0()31156/

*Fig.* 1 (*top*). *The prototype Xeronic machine can print lines 11½ inches in width at* 1,500 *a minute*

*Fig.* 2. *Facsimile of characters printed at* 1,500 *lines a minute*

Two associated companies of the Rank organization—Rank Precision Industries, Ltd.,* and Rank-Xerox, Ltd.—designed and developed the Xeronic printer. Rank-Xerox, Ltd., who already produce a range of manually operated xerographic document-copying equipment, are shortly to market an automatic continuous xerographic copying machine known as the Copyflo.

In the Xeronic printer there are two distinct sections: a xerographic printing-head, based on the Copyflo printing-unit, and the character translation unit, which is an electronic assembly. Xerography, the means by which the projected visual image is converted into a printed character, was invented in 1938. Serious commercial development of this technique did not begin, however, until 1947. This work was done by the Haloid Company, of Rochester, N.Y., U.S.A., with which firm the Rank organization is associated jointly in Rank-Xerox, Ltd.

The process depends upon the photo-electric properties of amorphous selenium. Selenium has the property of conducting electricity when illuminated, but in the dark, acting as an insulator. To make use of this property for xerography

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*Rank Precision Industries, Ltd., St. Andrew's House, 33, Mortimer Street, London, W.1.

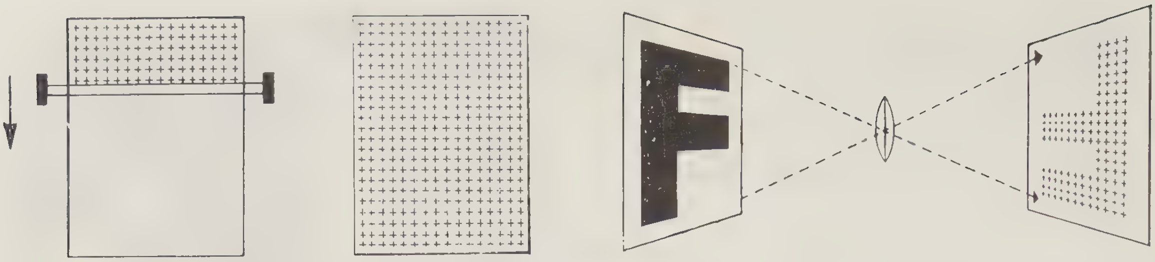

*Fig. 3. Sequence of operations when making a xerographic print. From left to right: charging plate with static electricity; uniformly charged plate; exposure, during which the charge will be dispersed from the illuminated areas; cascading black powder over the plate to develop the image; printing by bringing paper into contact with plate; image transferred on to paper; fusing image by heat*

amorphous selenium is evenly deposited as a thin film upon a metallic surface. A charge of static electricity is then induced upon the selenium surface. This is retained as long as the surface is kept in total darkness. Where light is allowed to fall upon the surface, the selenium becomes electrically conductive and the static charge leaks away.

If the image of a document is projected upon a charged selenium surface, the pattern of the electrical charge retained after the exposure will be a facsimile of the document. In order to convert this electrostatic image into a visual image for printing, black powder is cascaded over the surface. Powder will adhere to the charged, but not to the uncharged, areas of the surface. The powder image produced in this way may be arranged to be either a positive or a negative of the original document. A negative copy is produced, quite simply, by reversing the polarity of the free static charge induced on the selenium surface and using a black powder with different electrostatic characteristics.

A print is obtained by bringing a sheet of ordinary paper into direct contact with the powder-covered surface, when a quantity of the black powder will be transferred to the paper. This transferred image, a facsimile of the original document, is made indelible by the application of heat, which causes the special powder to fuse.

It was not until a machine—the Copyflo—had been developed to perform all these operations continuously and automatically that xerography could be used for high-speed computer output printing.

As stated earlier, the Xeronic printer has two distinct sections: the printing-head and the character translation unit. In the latter there is a permanent information store made up of a number of individual circuits, one for each character. When one of these circuits is triggered on receipt of the appropriate coded signal from the buffer-store of a computer or from a magnetic tape, it generates the required character, visually, on the screen of a cathode-ray tube. These trace-generating circuits are mounted on plug-in chassis that can be changed if it is wished to alter the range or style of the characters available for reproduction.

A letter or a numeral is represented in code by a group of the binary digits, or bits, 0 and 1.* In the codes that can be translated by the Xeronic printer, there are groups containing either five or six bits. A range of 32 separate characters can be represented by a five-bit code. This range can be extended, if required, by making each group of five bits represent two different characters. Two translation circuits are then needed and, before a code group is transmitted, a signal has to be given to indicate which particular circuit is to be used to translate the code and so trigger the appropriate trace-generating circuit. Using this technique a five-bit code can represent 50 or more symbols. Naturally with a six-bit code an even greater range of characters can be portrayed. Incidentally, the five-bit code translated by the prototype Xeronic printer is similar to that of the Elliott 402 computer.

The prototype machine receives signals from the magnetic tape unit in sequence, and each character is, of course, identified and projected on to the cathode-ray tube in the same sequence.

Characters are displayed individually on a standard commercial cathode-ray tube, 6in in diameter. They are arranged not in a single line but in two lines, one above the other,

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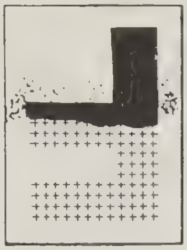
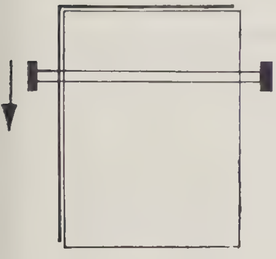
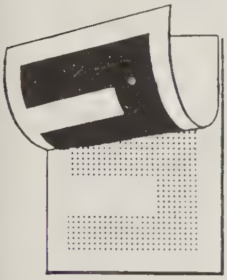
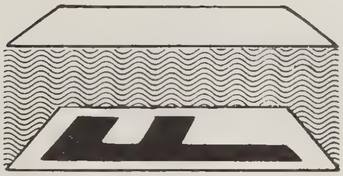
*An explanation of binary digits and the way they can be used to represent figures and letters is given in the article "The Universal Language of Computing" on pages 18-20.









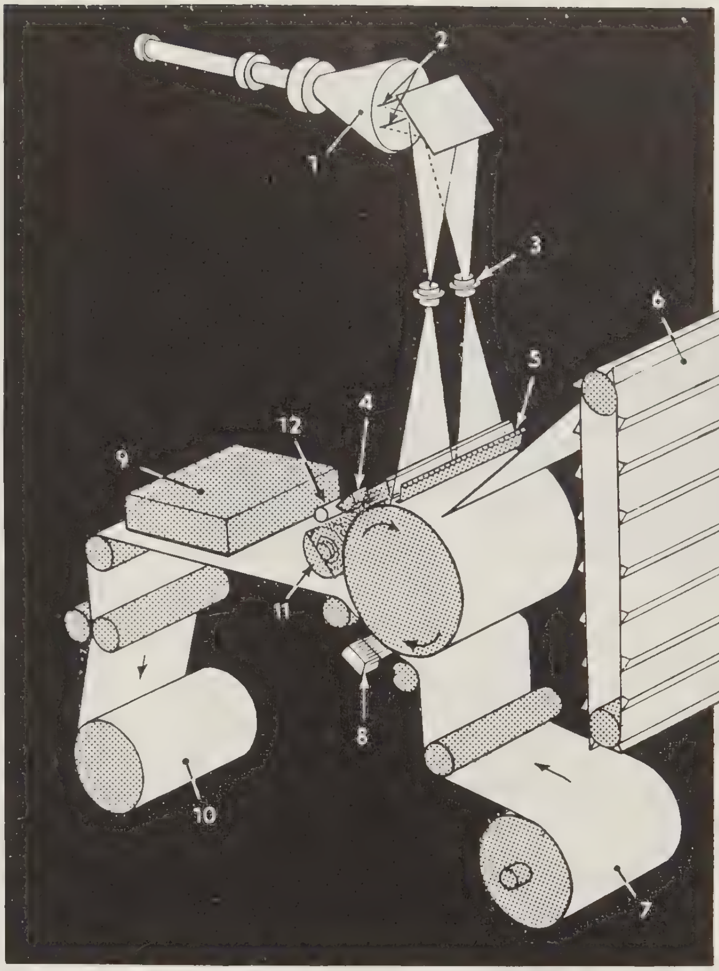


*Fig. 4. Method of continuous printing:* **1,** *Cathode-ray tube;* **2,** *Two lines of characters on tube;* **3,** *Optical system;* **4,** *Impressing static electrical charge on drum;* **5,** *Single line of characters projected on drum;* **6,** *Black developer powder distribution system;* **7,** *Paper feed roll;* **8,** *Transferring powder from drum to paper;* **9,** *Fusing unit;* **10,** *Paper take-up reel:* **11,** *Cleaning brush;* **12,** *Lamp for dispersing residual static charge*

which by means of an optical system become, when printed, one continuous line 11½ inches in width.

The various pieces of equipment needed for the xerographic process are arranged round the periphery of a selenium-coated drum, 15in in diameter, which rotates at 5 revolutions per minute. In the first operation, a free static electrical charge is induced on the selenium surface of the drum by an electrostatic unit. This consists of a number of wires that lie parallel to the axis of the drum and are supported a small distance above its surface. A high-energy electrical current passed through these wires creates a type of electrical corona discharge that causes a residual charge of static electricity to be left evenly distributed over the selenium-coated surface of the drum.

The charged surface of the drum next passes beneath an optical system. Characters, as they appear in sequence upon the screen of the cathode-ray tube, are projected on to the drum surface. The resultant lines are not straight, the characters having to be staggered to compensate for the continuous movement of the drum. Actual exposure time depends upon the size and form of the character projected but the average is 0·000175 second (175 microseconds). A complete line 11½ inches wide is exposed in a time of 0·0256 second.

After exposure the drum surface carries an electrostatic pattern that is a facsimile of the lines of characters projected individually upon the cathode-ray tube. A mixture of black powder and glass carrier-beads is then cascaded over the surface of the drum to develop the latent image. In order that each character should have a clean, crisp outline it is, of course, necessary that powder should adhere to the surface of the drum only as a result of electrostatic attraction and not because of normal adhesion. As the carrier-beads—themselves non-conductors of electricity—are circulated during the process, each bead becomes charged with static electricity as a result of mechanical abrasion and attracts the powder to it. When the carrier-beads pass over the surface of the drum they relinquish powder to the drum only where a greater electrical attractive force exists. After they have been cascaded the beads are collected and returned to the distributing hopper by a conveyor-belt ready for re-use.

Lines of characters are now delineated in black powder on the surface of the drum and a printed image is obtained by bringing a continuous roll of paper into direct contact with the drum. Another electrostatic unit, situated between the two contact-rollers, creates an electrical force that causes most of the black powder to be transferred from the drum to the paper.

The paper is then fed through the heated chamber of a fusing unit and a permanently printed record is obtained.

After this printing operation any powder remaining on the surface of the drum is removed by a rotating brush and, finally, any residual charge of static electricity is dispersed by illuminating the surface with a strong light. All is then ready for a repetition of the printing sequence.

### Printing rate

On the prototype machine the printing rate is 20ft a minute. The speed at which the paper is fed through the machine determines the line spacing and the printing rate. If normal single-line typewriter spacing is required—that is, six lines to the inch—1,500 lines a minute can be printed.

Higher printing rates can be attained only by increasing the number of lines per inch. In the near future, however, a machine with a paper feed speed of 40ft a minute is to be built and printing speeds of 3,000 lines a minute should then be possible, with single-line spacing. At the recent Computer Exhibition the prototype Xeronic printer was demonstrated receiving coded signals from a magnetic tape; these were decoded and the data derived were entered on pre-printed forms. Correct placing of the data on the forms is achieved by photo-electrically sensing marks provided along the margin of the pre-printed stationery.

Tabulation of the data to be entered on a form frequently occupies a considerable time, especially if the printing machine must scan each possible character position and advance line by line. An automatic tabulating system has, therefore, been devised. With this, each form is divided into eight vertical columns and eight horizontal strips. Every one of the rectangles formed by these divisions is given a coded address. Data to be printed are then prefixed by the appropriate coded address, and the machine will index immediately to this position and print out the data.

### Selective printing

By the use of this facility a subtle and valuable variation in the operational sequence can be obtained because the particular data printed on a specific form can be selected automatically from a quantity of associated data. For example, the magnetic tape may contain data concerning a particular transaction in which the customer's name, the items ordered, the price, the salesman's name and his commission follow one another in sequence. Each item will be preceded by a coded address indicating the position it is to occupy on the form. If an invoice is to be prepared for the customer, details of the salesman and his commission will not be required and, by using a wired plugboard without connections identifying these particular tabulation positions, this information will be excluded from the document printed. For internal business records, however, all the information is required and the plugboard used for invoicing is replaced by another, suitably wired, to print the complete data.

Another illustration of the flexibility of this machine when tabulating is that indexing from one position to another along the same line is so rapid that it is possible to print data at the beginning of the line, hop to the end of the line to enter some figures and then return and fill in any details in the middle of the line. Consequently, data to be printed on one line need not necessarily be supplied to the machine in the exact sequence in which it is to appear on the form. When a microfilming unit is fitted to the machine there should be no paper work to clear up on completion of a data processing operation because the microfilm provides the permanent record for the files.

Transistors are used throughout most of the electronic circuits. These circuits are assembled on removable chassis and servicing by replacement is therefore possible. A high standard of reliability for the complete printer is expected because of the small number of mechanical moving parts.

The prototype Xeronic printer is essentially a simple machine with the minimum of auxiliary equipment. It has been built to demonstrate that the high-speed printing of computer output data by xerography is possible. Several lines of development are being pursued that will considerably increase the scope of later machines of this type.

Important among these is a device to project the outline of the form at the same time as the output data. For this, a cylinder or film imprinted with the outline of the form required or, in fact, of several different forms, is fitted above the selenium-coated drum, adjacent to the cathode-ray tube on which the characters are projected. Through a separate optical system, the required form outline is projected on to the selenium-coated drum simultaneously with the output data, and the resultant combined image is printed xerographically on to the paper in the usual way. This technique overcomes the problem of synchronizing the paper feed with the data to be printed. It also permits more flexible operation.

Where the cylinder or film carries more than one form-outline, the computer output can be made to select automatically the appropriate form to be projected. Provision is being made to project any one of from 4 to 20 different designs of form. As pre-printed documents will no longer be needed a considerable saving in stationery costs will be possible.

In the future, machines will also be built to accept paper 26in in width. These machines will have duplicated cathode-ray tubes and optical systems. Identical signals will be fed from the character generation circuits to both cathode-ray tubes and two identical lines of characters will be projected and printed adjacent to each other. In this way both a primary document and a copy are prepared simultaneously.

Provision will be made to change the display so that four similar lines each 5½in in length can be projected. Where certain data are not to be printed on all copies of the documents produced, it will be possible to suppress, temporarily, the image appearing on one of the cathode-ray tubes. As the 5½in lines are projected in pairs—two from each tube—any data suppressed would be omitted from two of the documents. Thus it will be possible to produce four separate documents simultaneously by this means, each pair containing selected information.

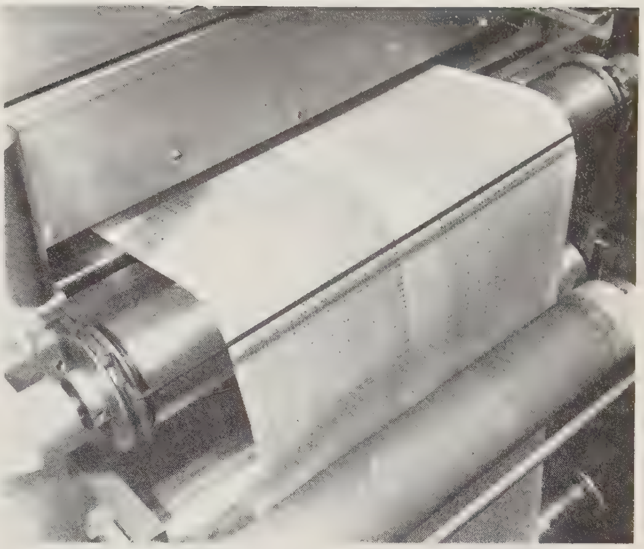


*Fig. 5. Printed paper emerges from the fusing unit on to the take-up reel at a speed of 20 feet a minute*

A range of four documents that could be produced in this way might be an invoice, a packing note, a stock record card and an accounts record card, with the price of the goods and the discount allowed suppressed from the packing note and the stock record card.

In this article, the Copyflo printing head has been discussed in relation to its inclusion in an output printer for computers. The Copyflo machine was developed for the rapid reproduction of business documents. In this form, the machine can produce facsimiles of original documents 15in or 26in in width, and of any length, at a printing speed of 20ft a minute. A microfilm unit can also be fitted and microfilm records may be selected automatically and printed at the same speed. However, although the Copyflo machine and the Xeronic printer share a common ancestry they are different machines. It is not envisaged, at this stage, that one machine will be built to do both types of work.

# Industrial inspection

## HOW MODERN METHODS DEVELOPED AND PROVED FOR OTHER PURPOSES CAN BE HARNESSED TO MAINTAIN CONTINUOUS CONTROL OF QUALITY: THE NEXT STEPS AND THE FUTURE

BY R. E. YOUNG, B.SC.(ENG.), M.I.E.E.*

AUTOMATIC control of industrial processes by "data," suitably presented, is now a generally accepted principle and is, indeed, practised by several of the continuous-processing industries. This technique has also reached the machine-shop, where it has been proved to be entirely practicable for data to be used to maintain automatic control of jig-borers and milling-machines.

So far, however, little has been done to apply similar methods to the essential industrial process of inspection. This is still largely carried out by human operators using visual methods, with the results dependent almost entirely upon personal capacity. And trained inspectors are increasingly difficult to find. As a result, of course, a bottleneck is often created, especially in the precision engineering industries where 100 per cent inspection is required. Thus, a strong case exists for speeding up inspection by the adoption of automatic data-handling methods, quite apart from the desirability of reducing the dependence of industry on a restricted source of suitable manpower.

In the writer's opinion there are three approaches that may well be adopted simultaneously in a given organization. The proportion of each method would depend upon the expenditure permitted by management after they have considered the length of production run, economies possible in manpower, and so on.

These three approaches may be summarized as: observed monitoring (accept or reject comparator systems); active monitoring (accept or reject comparator systems); gauging by apparatus with an electronic display.

In this context, monitoring may be regarded as a continuous detection process. An example is the electronic metal detector employed to check for the presence of foreign matter in the continuous flow method of manufacturing food.

With the observed system, warning of the occurrence of metallic contamination is given to the operator who must then take some action to reject the faulty product. It is a two-state system: either accept or reject (Fig. 1). Not only is the operator monitoring, in his function of observer, but he also exercises discrimination by deciding when and how to take action.

The diagram representing the active monitoring system (Fig. 2) is basically the same as that for the observed method, but control is effected by the accept or reject discriminator, which automatically energizes the appropriate actuators.

Such an automatic system is illustrated by the Allscott automatic package monitor which, it is claimed, can be set to check the contents of razor-blade packages and inspect these at the rate of 100 packages a minute. Rejection occurs because either there is an incorrect number of blades in a package or the metal content of the package is outside predetermined limits.

When the observed and the active monitoring methods are compared, however, neither shows overwhelming advantages over the other and a number of further factors must be taken into account before a choice is made.

The great attraction of the first method (observed monitoring) is its flexibility, because the inspection device presents information direct to the operator who then decides what action is necessary. On the other hand, the running costs of the second method (active monitoring) would appear to be capable of being made much lower than observed monitoring. The cost of the razor-blade checking operation quoted is stated to be 0·005 pence per package.

The degree of flexibility required of the inspection system will be influenced by the extent of action demanded and, of course, the scale of manufacture.

Since much of the basic design of the monitoring systems depends upon the comparator, a more detailed examination of its principles is needed. Most comparators operate by making a comparison between some electrical property of the test-piece and an established standard. This is a development of the classical Wheatstone

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*Mr. R. E. Young is Chief Electronics Engineer of Sir W. G. Armstrong Whitworth Aircraft, Ltd.

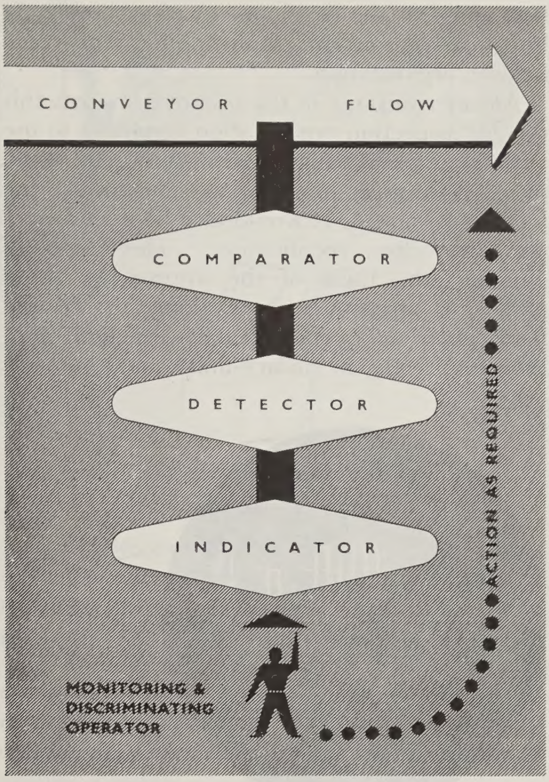


*Fig. 1. Observed monitoring where the operator decides when, and how, to take action to reject faulty work*

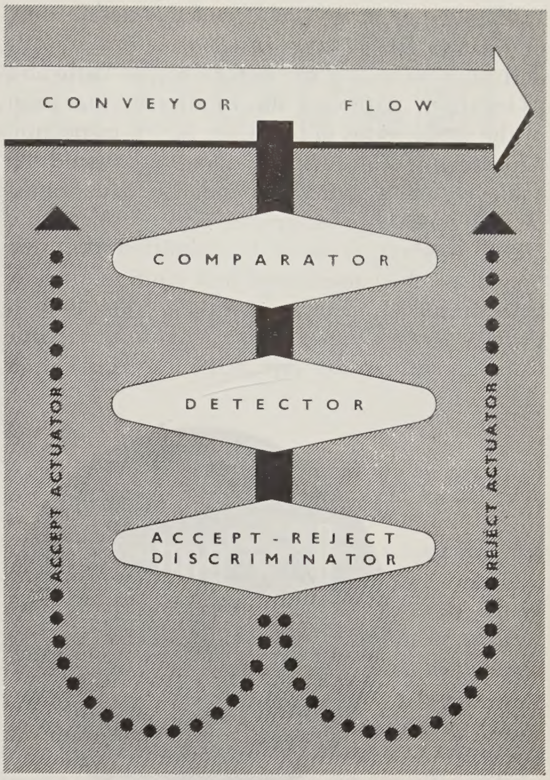


*Fig. 2. Active monitoring where faulty work is rejected automatically by actuators controlled by a discriminator unit*

bridge, where the standard is the known arm of the bridge.

The standard provides all the data required for the purposes of inspection. Therefore, just as a conclusion obtained mathematically is only as good as the assumptions on which it is based, so the indications obtained from the comparator are only as good as the standard used. Hence, the overall tolerance of the monitoring system should be regarded as being compounded of the tolerances of the standard and those of the remainder of the system.

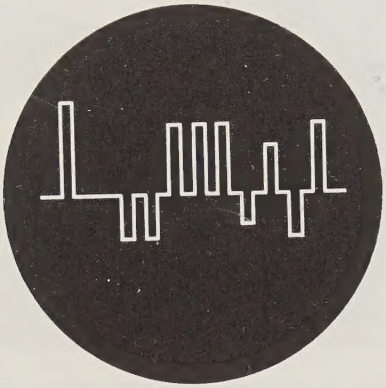
In practice, an actual component is often chosen as the standard. In the razor-blade manufacturing process quoted a selected package is used as the reference. The choice of this reference must obviously be made with great care: its characteristics must place it in the middle of the tolerance-band, otherwise rejections will be weighted in one direction or the other. But where it is difficult to select a suitable standard, a sample may be simulated—that is the inspection information is established in another form to avoid the weighting effect. Whichever form of reference is used, there will be a statistical effect on rejection because of the cumulative errors, which are difficult to allow for when one is dealing with marginal cases. This problem can be overcome to a great extent by giving a human operator the opportunity to re-examine the rejects in order to assess their true value. Also, the operator can determine whether a rejection is only a random occurrence or a systematic fault in the production line. This ability to re-examine rejected products promptly is a great advantage, particularly where the inspector intervenes before a systematic fault has done more than produce the first of what would be a faulty batch.

If the examination of rejects is accepted as desirable, even if only for information and not necessarily for rectification, then there is much to be said for the flexibility of the observed system. With the active method a large rejection rate may build up and be held for some time before anybody is in a position to appreciate the fact. In other words, true information regarding the operation of the process is only obtained after a considerable delay. In both systems, a faulty product is rejected.

The "go or no go" nature of this action may be taken a further stage in which information is derived concerning the nature of the fault and its location. Although this implies an alteration in the usual terms of reference for an inspection department, considerable economy would be achieved if this procedure could be made a part of an expanded "accept or reject" operation. Here, however, it must be admitted that the type of product monitored in a continuous flow manufacturing system is usually one that is thrown away if faulty, rather than one capable of being successfully repaired in a rectification section. Nevertheless, it is possible to devise equipment which performs an elementary, graded selection process.

In such a process, as applied to electronic components such as resistors, which are supplied in various tolerance ranges, the degree of departure of a given unit from the standard determines the particular (tolerance bracket) bin into which the unit is directed. Graded selection of this type may be regarded as the first phase of the development of a completely integrated monitoring, fault-finding, fault-rectification organization.

An interim stage in the progress towards this type of inspection organization would be to use various forms of gauging with visual electronic display to give information concerning the location of faults. It would also be used for rechecking after rectification. This type of gauging, the third of the approaches listed earlier, is already being exploited in certain fields such as ultrasonic flaw-detection and, more indirectly, in surface-finish measurement.



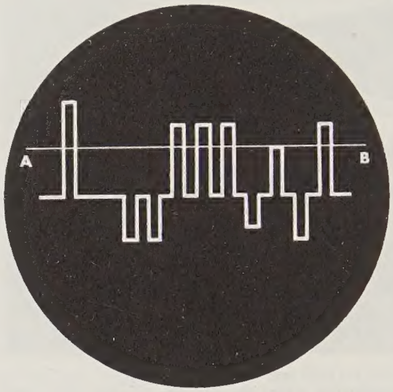


*Fig.* 3 (*above left*). *Data presented as a stepped graphical display on a cathode-ray tube. Each step represents a measured value*

*Fig.* 4 (*above*). *An electronic cursor-line AB can be adjusted by the operator and a calibrated measurement made of individual "steps" of the display*

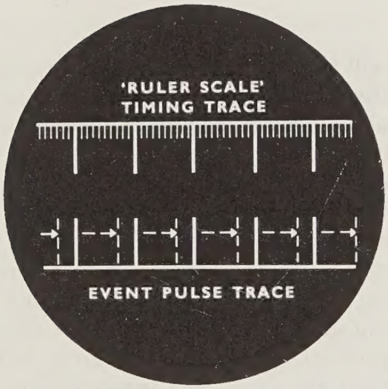


*Fig.* 5. *Graphical display in which quantities to be measured appear as a pulse pattern below a calibration scale*

By the full use of the human intelligence, which is implied when displaying information in this way, and with sufficiently good cathode-ray tubes or similar visual presentation facilities, it is possible to obtain quite far-reaching interpretations of the "pictures" shown. By combining these facilities with the observed and active monitoring methods previously discussed a comprehensive inspection system could be produced. Such a system would have much in common with the methods used in telemetry and may therefore be regarded, at least, as partially proved. Telemetry is the technique of obtaining accurate information from the item being measured, converting and transmitting it by radio, or cable link, to a recording station. These techniques have been intensively developed, since the war, to meet the need to record data regarding flights made by guided missiles, and more recently earth satellites.

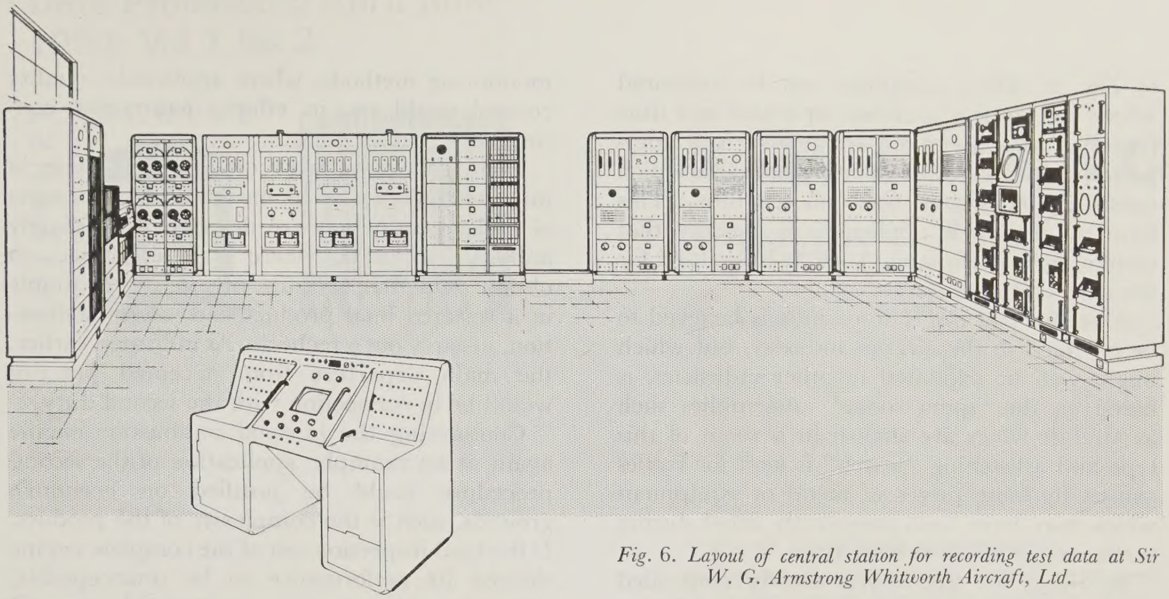


*Fig. 6. Layout of central station for recording test data at Sir W. G. Armstrong Whitworth Aircraft, Ltd.*

In the design of such an inspection system the ultimate aim should be to provide a better understanding concerning what is wrong with a product. The technique is the manipulation of data into more usable forms: for example, during a test, the changing of performance data recorded as magnetic signals into electrical signals and, in turn, their conversion into a graphic display.

Mr. George W. Hoover, of the U.S. Office of Naval Research, has discussed information displays relative to control systems involving men and machines.* His paper "Control in Man-Machine Systems" is concerned mainly with an airborne "vehicle," but the philosophy is applicable to a far wider range of man-machine systems in which data conversion takes place. It is stated that the information display must be the most important design criterion once the desired performance specification has been laid down. It is also stated that the design of the various elements of the automatic system should be dependent upon that of the display.

Even without agreeing with the whole of this thesis, one can accept its force where the importance of methods of presentation of information to the human operator is concerned. It follows, then, that the efficiency with which the data are rendered more "usable" is a measure of the goodness of the display; and this principle can be taken further by saying that the information should be presented in a form that can be assimilated by the observer without ambiguity.

In applying these ideas to the inspection, for example, of an internal combustion engine, mechanical out-of-balance should be shown in such a way that the operator would be able to distinguish by how much the out-of-balance exceeds the acceptable limit, and whether it is occurring only at a certain rotational speed or over a wide range of speeds, and at what point in the operational cycle it builds up. It is likely that the most satisfactory medium for a visual display is the cathode-ray tube presentation such as that shown in Fig. 3. Here, the various physical conditions being measured would be indicated in stepped graphical form, and a superimposed transparent mask used for identification. Abnormality of a particular quantity would be indicated by its appearance outside the limits marked on the mask.

Experience accumulated over a number of years by Armstrong Whitworth Aircraft confirms that observers, as they become familiar with such graphical displays, learn to extract much physical information from them. With the addition of an electronic calibration system† it is possible to obtain accurate measurements of the various quantities shown in relation to either a frequency or a time standard.

In Fig. 4 this system is illustrated as applied to a stepped graphical display; the electronic cursor-line AB can be adjusted by the operator to bring it into coincidence with a particular step to be measured. By interposing a simple conversion stage, the observer can obtain an accurate reading, in the appropriate units, of the particular quantity required, this while the component is under working conditions. Another method of presenting data is illustrated in Fig. 5. Here quantities can be measured where they appear as pulses separated in a time pattern. Measurements are made by a comparison with the ruler scale timing marks which constitute the second trace on the tube. This form of display is applicable to devices that employ pulse techniques, such as those used for the detection of flaws.

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* *Control Engineering*, March 1958.

†British Patent No. 744,345, "Telemetry Calibration System."

A category of inspection which is believed to be confined to the aircraft industry, but which might well be exploited in other industries, is based on the "quiet room." Assemblies such as aircraft wings are shaken in a room of this type and a listening "watch" is kept for rattles caused by loose pieces of metal or equipment which may have been incorrectly fitted during earlier stages of manufacture.

By using for the test a closely controlled shaking mechanism, in conjunction with a microphone and amplifying system, it should be possible not only to detect defects more easily, but also the cause and the seriousness. The main presentation would be by a cathode-ray tube display linked to the frequency of the shaking mechanism, and in this case it would probably be advantageous to have a loudspeaker as a secondary indication.

Yet another form of inspection, the problems of which could be reduced by electronic means, even if not overcome completely, is the simultaneous examination of parts separated physically by a considerable distance or difficult to view by conventional optical methods. Television suggests itself for dealing with such problems, and has already been used with apparent success by the United States aircraft industry.

A parallel application by Armstrong Whitworth Aircraft has been the use of television* to view a micrometer gauge at a remote point. Here again, taking television as a subdivision of telemetry, it will be seen that the requirement for an inspection measurement following development and manufacture was covered by a relatively conventional form of data handling.

By gathering together the various techniques described—techniques shown to be capable of leading to an interim stage of supra-inspection—one can visualize the final phase being entirely practicable. And by the use of developed flow monitoring methods, where applicable, quality control could be, in effect, maintained continuously.

The remaining tasks of this new type of inspection force are to ensure that the causes of faulty production are detected immediately and cleared, and, where it is economic, to obtain data that specifies precisely the trouble in a rejected final product and, after rectification, to carry out a recheck. As indicated earlier, the main departure from accepted practice would be in connection with the second duty.

Considering the internal combustion engine again as an example, application of the second procedure could be justified on economic grounds, such is the complexity of the product. If the final inspection test of the complete engine showed its performance to be unacceptable, then it is possible to conceive a suitable comprehensive test-rig for fault location. The engine would be fitted with a number of gauges to measure the pressures in all cylinders, the out-of-balance forces and vibration frequencies at various points, and so on.

The engine would be driven at different speeds according to a predetermined programme, and the various results recorded on magnetic tape. By playing back the tape and converting the recorded data into a visual display, as already described for electronic gauging, inspection and the location of faults could be performed subsequent to the test. It might be considered worthwhile installing a complete recording system for each test-rig, but unless the rejection rate were high the expenditure involved would be heavy in relation to the intermittent use made of the equipment.

An alternative is to build a central station equipped with a recording service and linked by land line or similar means to the various test-points. This method would involve a relatively small capital cost. The division of time between the various user departments could be arranged without undue difficulty. Such a sharing system has been evaluated over a long period by Armstrong Whitworth Aircraft. Fig. 6 shows the central recording station now being brought into operation at the Whitley works of the firm.

Eventually, assuming that fault rectification continues to be accepted as worthwhile for complex products, the entire inspection procedure may become completely automatic. But this does, however, imply the development of associated complex electronic data-interpretation systems coupled with almost equally complex arrangements of transfer actuators.

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*British Patent No. 742,983. This application is described in an article in the *Hawker Siddeley Review* for March, 1956, on "Radome Development," in which it is noted that this is a comparatively simple method of relaying a small mechanical movement to an observer without introducing "backlash" or similar errors.